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JOURNAL
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Industrial Uses of Reclaimed Sewage Effluents

By N. T. Veatch

A modified version of a paper presented on July 23, 1947, at the Annual Conference, San Francisco, in joint session with the Federation of Sewage Works Assns., by N. T. Veatch, Partner, Black & Veatch, Cons. Engrs., Kansas City, Mo. The original paper included a census, in tabular form, of sewage effluent reclamation in the United States, summarized herein, and discussions by Earnest Boyce and Ray F. Goudey, omitted for lack of space.

THE desire to salvage something of value from sewage is not new; in fact, considerable accomplishment has been made along that line since the time water-carriage collecting sewers came into existence nearly a century ago. The first use of sewage effluent was for irrigation, many of the early systems combining the salvage of water and the disposal of the sewage in broad irrigation. This practice is still followed in a few instances.

Values in Sewage

The utilization of sewage sludge for fertilizer has received much study, and its practicability is evidenced by the practice at Milwaukee, Chicago and elsewhere. Generally speaking, the salvage of sewage solids, though proven feasible, has resulted only in the reduction of total cost of sewage treatment rather than in actual profits to the complete process of sewage disposal. The primary reason for this is that sanitary sewage ordinarily contains about 0.03 per cent of recoverable materials other than water and therefore must be classed as unusually "low-grade ore" so far as processing is concerned.

A second reason, which applies particularly to the manufacture of fertilizer, is that in each case the source of raw material is strictly limited by the size of the community served. Mass production methods are feasible only in very large installations, and therefore unit costs of production, so far as the plant of ordinary size is concerned, are relatively high compared with those of commercial enterprises which may obtain raw material as needed. Where actual profits have been realized, it has been due to the value of the water as such, rather than to that of any other ingredient of the sewage.

It seems probable that the salvage of the water in sewage, for uses in which human consumption is not involved, may be more generally attractive from

an economic standpoint than the salvage of solids, and therefore deserves more attention from those engaged in the water and sewage works fields than it has received in the past.

The use of sewage and sewage effluents for irrigation is well established, and in arid or semi-arid areas it represents a salvage value far in excess of that possible from the solids in sewage. Due to climatic and topographic limitations, however, it is probable that this method can never have general application.

Feasibility of Industrial Usage

Relatively recent and undoubtedly successful experience with the use of sewage effluents for industrial purposes indicates that this use may represent a real economic possibility. In a number of instances the costs incident to the successful use of effluent have been found to be less than those involved in the development of an equal amount of additional water, and it is pertinent to note that unless unusual amounts of soluble mineral salts are involved, the treatment required is neither difficult nor expensive. A survey of the general practice in this country brings out the facts that:

1. The use of sewage effluents for industrial purposes is limited to a relatively few instances.
2. Such use is limited to instances where an adequate supply from ordinary sources is either very expensive or actually not available.
3. The problems involved in fulfilling the requirements of the public health and of the industry simultaneously are actually not difficult.

It is probable that in the majority of cases the use of sewage effluents is a matter for future rather than immediate consideration, but it is a fact that in many instances the demand for water is increasing, while the development of additional water is relatively expensive or even impractical.

Industrial requirements for water are quite varied in quality but are commonly relatively uniform in demands. Seasonal peaks are usually less prominent than those due to other municipal uses, particularly sprinkling. There are some exceptions, but in general the industries which can use treated sewage—where human consumption is not involved—operate on a fairly even basis throughout the year. This is an important factor, particularly when several months of storage is a part of the water supply works, since if the relatively even industrial demand is met from another source, more of this storage becomes available for use during seasonal peaks of ordinary demand.

In perhaps a majority of cases the sewage flow of the city is at least as great as the demands of its industries, and it follows that, so far as the latter are concerned, provision for the use of sewage effluent, when economically justified, assures an ample and cheap water supply.

Case Histories

In the preparation of this paper, letters were sent to the engineers of all state boards of health in the United States, asking for a list of places, if any, where salvage of sewage effluents was practiced. Answers were received to all letters sent out, and it is desired to acknowledge and express appreciation for this assistance. A 100 per cent reply to any questionnaire is unusual and certainly worthy of special acknowledgment.

From the information gained from the state sanitary engineers, and from direct correspondence with the cities

making use of sewage effluents, it was determined that there were apparently only nine places in this country where sewage effluents were being used, or contemplated, for industrial purposes. In only four of these was revenue being derived which could be credited to sewage disposal operations.

It is doubtful that the studies back of this paper could be considered conclusive regarding the actual number of instances where sewage effluents are being salvaged for industrial purposes, but it does establish the fact that the number is very small.

The nine reported instances in which sewage effluents are reclaimed for use in industry are described briefly herein.

Herington, Kan.

The east central Kansas city of Herington has a population of 3,800 and is a division point on the Rock Island Railroad. The problem of water supply is particularly difficult since there are no permanent streams and the ground water is highly mineralized. The only source of satisfactory water is impounded surface runoff and the city has developed the only really feasible reservoir site within reasonable distance.

Prior to 1934, the Rock Island Railroad obtained its water supply from wells located fairly close to the site of the proposed sewage treatment plant. Studies disclosed that it would be possible to furnish a purified effluent from the treatment plant at a price that would make the disposal of sewage self-liquidating, and at the same time result in appreciable saving to the railroad in cost of softening. The demand of the railroad was less than the available sewage flow, so a definite and satisfactory water supply would be assured if arrangements could be made for the railroad to abandon the wells and purchase sewage effluent.

While it had no particular bearing upon the situation at Herington, the demands of the railroad represented approximately half of the supply available from the city's impounding reservoir. It would have been impossible for the city to supply the railroad from its domestic supply without going to a great deal of expense in developing additional supply. This is considered to be an important point, as in many cases the advisability of using sewage effluent hinges on the economic balance between the cost of additional supply and the purification of the effluent.

In order to make a softer water available to the railroad, as well as to create a source of revenue to the city, an agreement was made in 1933 whereby the city delivers effluent from its activated sludge plant to the softening plant of the railroad under a sliding scale of rates which ranges from 5¢ to 7¢ per 1,000 gal. delivered.

This plan has been in continuous and successful operation since early in 1934, and an analysis of the revenues and disbursements during the past thirteen years shows a balance of $1,668.43, as follows:

Total receipts (all sources)	$103,554.17
Total disbursements for same period (inclusive of operation, maintenance, interest and the retirement of $39,000 of the original bond issue of $65,000)	101,885.74
CASH ON HAND JAN. 1, 1947	$ 1,668.43

The pertinent facts disclosed by this record are:

1. The industry has enjoyed and is enjoying the use of a satisfactory water supply at costs much lower than those involved in the development and use of any other available source. The re-

cent extension of the original agreement at the request of the industry is substantial proof that the effluent is satisfactory.

2. The city water department is furnishing a service that would be impossible without a sizable additional capital outlay.

3. The sanitary sewage has been given highly satisfactory treatment for a period of thirteen years at no expense to the city, and there is no reason to doubt that revenues will equal costs in the future.

A further breakdown of the disbursements during the thirteen year period is:

Operation and maintenance	$ 32,335.74
Interest	30,550.00
Retirement of debt	39,000.00
TOTAL FOR 13 YEARS	$101,885.74
AVG. ANNUAL DISBURSEMENT	$ 7,837.36

The average annual disbursement actually represents the cost of sewage disposal which would, ordinarily, have been met by taxes. The tax equivalent is therefore $2.06 per capita or approximately 2.5 mills per dollar of assessed valuation.

It is interesting to note that the debt has been retired at the uniform rate of $3,000 annually, which is 4.6 per cent of the capital investment of $65,000 and is the rough equivalent of the annual depreciation of the sewage treatment plant.

Grand Canyon, Ariz.

Possibly the earliest installation for the reclamation of sanitary sewage for industrial use is at Grand Canyon, Ariz., where water from springs costs about $2.00 per 1,000 gal. and water hauled in railroad tank cars about $3.00 per 1,000 gal.

The sanitary sewage, after treatment by the activated sludge process, is coagulated, filtered and sterilized prior to distribution to uses which include stationary boilers, locomotives, toilet flushing and lawn irrigation.

Due to the nature of the development at Grand Canyon, which is a resort of the highest class operated jointly by the U.S. government and the Santa Fe Railroad, the treatment of the sewage is unusually complete. Conventional methods for the purification of both sewage and water are employed, and a characteristic analysis of the reclaimed product is: 5-day B.O.D.—1.5 ppm.; suspended solids—trace; *Esch. coli*—less than 1 per cent of 10-ml. test portions showing presence of *coli-aerogenes* group. In other words, outside of its questionable past, the reclaimed effluent is good drinking water. Regardless of its safe quality, the effluent is distributed in a separate system of pipes of which all visible portions are painted a bright red. Warning signs are prominently placed at points of possible use and connections are made under rigid regulations.

The cost of the reclaimed effluent is reported by John O. Cook (1) to be 30¢ per 1,000 gal., which, while quite high from the standpoint of sewage disposal, is from 10 to 13 per cent of the cost of water from any other available source.

The amount of effluent is relatively small (approximately 150,000 gpd.), but due to unusual conditions its use is relatively important economically.

Corpus Christi, Tex.

For a period of about two years during the late war, the effluent from a trickling filter at Corpus Christi was used by an oil refinery for cooling and condensing. It was found that the control of slime by chlorination was a

necessary treatment step but that the effluent so treated was satisfactory. The effluent was used until the plant was shut down and dismantled.

In describing the operations at Corpus Christi, S. L. Allison, Supt. of the Sewer Dept., made the following pertinent statement:

> Circumstances created the market for sewage effluent before the effluent was available. This market was caused by the adjacent oil fields furnishing a high grade gasoline crude oil, tide water shipping, and an overloaded city water system.

Unusual conditions existed, therefore, which made the salvage of sewage effluent necessary and desirable.

The revenue from the sale of effluent ranged from \$486 to \$625 per month and was expected to go to more than \$100 per day with enlargement of the refinery. The plant is now shut down.

Baltimore, Md.

So far as quantity of effluent is concerned, it is probable that the experience at Baltimore should head the list. In this case, a substantial portion of the effluent is sold for cooling, quenching and possibly other uses in steel mills. The Baltimore experience has been described in detail by Abel Wolman (2).

Big Spring, Tex.

Approximately one-half of the effluent from the sewage treatment plant which serves the city of Big Spring, Tex., is being purchased by an oil refinery for use in cooling and as boiler feed. The plant is of the contact aeration type and the effluent is stored in an earthen reservoir from which the portion used by the industry is pumped as needed, by its own equipment.

The usage amounts to approximately 18 mil.gal. per month and produces a revenue of about \$800 per month, or roughly 90 per cent of the cost to the city of operating and maintaining the sewage works.

The effluent, after chlorination for slime control, has been satisfactory, and its use represents an estimated saving to the industry of 5¢ per 1,000 gal., or about \$10,800 per year, as compared with the costs involved in the development and use of ground water, which is the only other available source. The ground water is limited in quantity and unattractive from the standpoint of mineral content.

Enid, Okla.

Due to the inadequacy of the original ground water source, a large portion of the water used by an oil refinery at Enid, Okla., is taken from an intermittent stream, the dry weather flow of which is the effluent of the trickling filter plant serving the city of Enid. The effluent is clarified in a tank of the "Accelator" type at the refinery, and is used for cooling and as boiler make-up.

The current program of sewage treatment for the city involves the use of a site below the refinery, and it is interesting to note that the industry plans to construct a pumping station at the plant outlet in order to get the effluent directly and escape the periods of high turbidity in the stream.

Here is a case where it would seem that the city should be getting some revenue for providing a water supply to the oil company.

Duncan, Okla.

A refinery at Duncan, Okla., uses water from an intermittent stream,

under conditions similar to those at Enid, and gives it similar treatment.

Goldfield, Nev.

Due to a chronic shortage of water, settled sewage from the municipal sewage treatment plant is used in metallurgical processes at a local mill which employs the cyanide process.

Providence, R.I.

Sewage treatment plant effluent is used for cooling purposes at the near-by municipal incinerator.

Cheyenne, Wyo.

The production of an industrial water supply from the effluent of a proposed sewage treatment plant of the trickling filter type has been studied and has been given favorable consideration by the Cheyenne, Wyo., Board of Public Utilities, which operates both the water works and the sanitary sewer system.

It is estimated that the current demand of industries for purposes which do not involve human consumption is approximately 3 mgd., and that the plant effluent may be softened, filtered and delivered to the customers' premises at a total cost of approximately 4½¢ per 1,000 gal. This cost is lower than that of furnishing water from the municipal supply and a great deal lower than that of developing and furnishing the same amount of water from any other available source.

Conclusions

The experience at the nine cities mentioned above is not presented as a complete outline of the use of sewage effluents for industrial purposes, but rather as evidence that such use is actually feasible and can be economical.

It will be recognized that three conditions must exist simultaneously in order to make the plan worthy of consideration:

1. There must be a local industry in need of water for purposes that do not involve human consumption.
2. There must be a sewage treatment plant large enough to furnish the amount of effluent required.
3. The costs of processing and furnishing effluent must be less than those involved in the use of another source of supply.

With the foregoing in mind, it is interesting to know that the reclamation of sewage is a step that can be taken when the necessity arises and that a great deal of the aversion to the use of sewage in any form is actually unwarranted. As a matter of fact, the effluent from a modern sewage works of the complete treatment type is a better supply than many raw water supplies that are being purified for domestic use. Surely there can be no good reason for not salvaging sewage effluents for industrial purposes when the practice is economically justified.

There may even be cases where the salvaging of sewage effluents for re-use as domestic supplies would be justified, but such a practice would undoubtedly have to be camouflaged in some way to overcome public resistance. A survey made by the Kansas State Board of Health a number of years ago indicated that during the summer months the total river water used by cities along the Verdigris River in Kansas was 17 times the total flow of the stream at the state line, where the stream left the state. Undoubtedly, sewage effluents were being salvaged for domestic use in this instance.

As to the feasibility of using sewage effluents for industrial purposes, from

the standpoint of the industries themselves, there are examples all over the country where such water supplies are so used. A good example is the situation along the North and South Branches of the Chicago River, the flow of which is made up largely of treated sewage. Here the water from these streams is in rather general use by industries for cooling and condensing. The natural inference is that this source is used in preference to the public supply for reasons of economy. There are many other similar examples.

Many cities can, by the salvage of sewage effluents for industrial purposes, extend materially their ability to offer adequate water supplies to prospective industries. The potential water supply available from sewage effluents is enormous and should not be overlooked where conditions and economics warrant. Sewage treatment plant effluents should be considered as a natural resource, and where at all possible, the cities supplying them should arrange to sell them as a definite commodity. As a product of the sewage system, the revenue from the sale of treated effluents would be credited against the cost of the service.

Census of Effluent Utilization

Some idea of the extent of sewage effluent utilization in the United States may be obtained from data supplied by or through the various state sanitary engineers and from a study by Wells A. Hutchens of sewage irrigation in the western states (3), published in 1939. Sewage effluents were being utilized at 135 localities in 18 states. The salvaged water was used agriculturally in 124 places. It was used for cooling purposes by oil refineries (at Duncan, Okla.; Enid, Okla.; Big Spring, Tex.; and Corpus Christi, Tex.); by steel mills at Baltimore, Md., and Salt Lake City, Utah (Geneva Steel Co.); and in the municipal incinerator at Providence, R.I. Railroads at Herington, Kan., and Cheyenne, Wyo., employed reclaimed effluent for boiler water. At Goldfield, Nev., it was used in the processing of ore, and Grand Island, Neb., utilized it in a skating rink.

Acknowledgment

Grateful acknowledgment is made to the city engineers, sewage works superintendents, state sanitary engineers and others who furnished much of the information set forth in this paper.

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2. Wolman, Abel. Industrial Water Supply From Processed Sewage Treatment Plant Effluent at Baltimore. Sew. Wks. J., **19**: (Jan. 1948).
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Some Aspects of the Requirements for the Quality of Water for Industrial Uses

By Sheppard T. Powell

A paper presented on July 23, 1947, at the Annual Conference, San Francisco, in joint session with the Federation of Sewage Works Assns., by Sheppard T. Powell, Cons. Chem. Engr., Baltimore, Md. Lack of space necessitates the omission of A. M. Buswell's discussion of this paper.

THE variety of consumers of water for industrial purposes is so great, and the specific physical, chemical and bacterial requirements cover such broad limits, that no standard specifications for water quality are possible. In the industrial field, water should be considered as a raw material which must be processed to meet specific needs. It is obvious, even on casual reflection, that water suitable for one industrial process may be totally unsuited for the requirements of a dissimilar industry. Further, the demand for water of different quality in the same industry changes as the processes improve or develop. Since the selection and treatment of water in industrial processes are not subject to standardization, it is possible to discuss water quality only in general terms and to evaluate specific demands for certain purposes.

Due to the fact that stream pollution is becoming increasingly important with regard to its effect upon the quality of raw water, this is given consideration in the present paper wherever it is relevant to the subject under discussion. In many areas the problem is complicated not only because of the quality of the water available, but because of its scarcity. Securing an ample supply of water from underground or surface sources, either for large industries or for areas where there is great concentration of industrial development, often becomes an insurmountable task. It is for this reason that recourse has been made, in some cases, to the use of treated sewage; and it is conceivable that the utilization of such waste water may increase as time goes on. Undoubtedly this source of water will solve many water shortages, but likewise it may introduce new problems which will require solution to avoid costly operating difficulties.

American industry is often prone to undertake radical steps in matters of this kind without sufficient investigation or intelligent evaluation of the hazards involved. This paper has been prepared to present certain phases of the requirements of industry with respect to desired quality of water and to warn against the widespread use of sewage effluents until all engineering and economic phases of the undertaking have been surveyed.

Industrial Uses of Water

There are so many uses for water in industry that a complete list of such requirements cannot readily be cataloged. It would be impossible to pre-

sent in this paper specific chemical and bacteriological requirements in the great number of industries where water is essential for processing and other uses. The discussions will be limited to certain industries where the volume and quality of water become an all-important requirement. The operation of such industries, as related to their water supplies, is given merely to illustrate the problems rather than to cover the entire field. In general, however, the major needs fall within one or more of the groups classified in Table 1.

TABLE 1

Uses of Water in Industry

General Class	Typical Usage
Cooling Water	Surface condensers Heat exchangers Jet condensers
Processing	Water entering product Supplementary use in the manufacture of the product, such as washing, etc.
Boiler Feed	Steam generation
Sanitary	Drinking water Showers, washroom and toilet facilities
Fire Protection	General fire protection Sprinkler systems
Air Conditioning	Humidification, cooling and washing
Miscellaneous Uses	Clean-up water Lawn sprinkling, gardening, etc.

Cooling Water

The largest single use of water by industries is for cooling purposes. The volume and the temperature of the cooling supply are of the greatest importance and can be specifically evaluated on a dollar basis. These requirements take precedence over the quality of the supply, and rightly so; however, water quality cannot be ignored, especially when dissolved salts, gases or by-products which are present have an adverse effect on the heat-exchange equipment.

Cold water is essential for many processes, especially in the chemical industries. The effect of temperature on the economic value of a water supply is a phase of water engineering of the greatest importance to industries. Recognition of this is reflected in a study of temperatures of industrial water supplies, published by the U.S. Geological Survey in 1925 (1). For many industrial uses the temperature of water is the governing requisite, and the selection of plant sites is based frequently not only on the availability and volume of a water supply but also on its temperature.

Table 2 shows the summer temperatures of well water, as delivered to consumers, at various locations in the country (2, 3). Table 3 is a record of the temperatures of surface waters for many cities in the United States (2, 3). The temperature of surface supplies and well waters obtained from shallow depths approaches, and fluctuates with, the temperature of the air. The temperature of deep well supplies is relatively uniform.

A marked increase in the temperature of surface water, above that normally expected, is caused by the discharge of hot or warm waste or cooling waters into rivers and lakes. In certain densely developed industrial areas this condition becomes pronounced. As an illustration of this, the mean air temperatures and the corresponding water temperatures of the Mahoning

River at Youngstown, Ohio are plotted in Fig. 1. This river flows through a highly industrialized section, and, within a few miles, the river water is re-used for cooling water many times by a number of steel mills. From these records it is obvious that the thermal value of the water is materially depreciated for cooling purposes, especially when the temperature requirements of certain equipment must be limited to a specific range. Similar conditions exist in other industrial areas, and it is surprising that the problem has not received more attention, since it involves financial losses which can readily be calculated and related to plant efficiency and economy.

For ordinary cooling and condensing operations the temperature of the available water supply may not be particularly important, but some processes have critical cooling water temperature ranges. The great demand for cold water to meet requirements has in some cases been responsible for overconcentration of industries in areas where cold underground waters are available. The partial or total exhaustion of such supplies is traceable to these heavy demands. Well failures of considerable magnitude are now occurring in many areas of the country. The depletion of ground water has made it necessary to utilize surface water in ever-increasing amounts and to resort to cooling towers and other facilities.

Recently the author studied the water and temperature requirements for a large manufacturer. It was found

TABLE 2

Summer Temperatures of Municipal Water Supplies for Various Cities Using Wells as a Source

Location	Temp. at Main Outlet °F.			
	June	July	Aug.	Sept.
Albuquerque, N.M.	72.0	72.0	72.0	72.0
Aurora, Ill.	60.0	60.0	60.0	60.0
Camden, N.J.	58.0	58.0	58.0	58.0
El Paso, Tex.	84.0	85.0	85.0	84.0
Fresno, Calif.	72.0	72.0	72.0	72.0
Houston, Tex.	84.0	84.0	84.0	84.0
Jacksonville, Fla.	84.8	86.3	86.7	82.4
Kalamazoo, Mich.	52.0	52.0	52.0	52.0
Lafayette, Ind.	53.0	53.0	53.0	53.0
Lansing, Mich.	57.5	58.0	59.0	59.0
Lincoln, Neb.	58.0	59.0	59.0	59.0
Lowell, Mass.	50.0	50.0	50.0	50.0
Madison, Wis.	53.0	52.0	52.0	53.0
Marion, Ind.	54.0	54.0	55.0	55.0
Montgomery, Ala.	70.0	70.0	71.0	71.0
Pensacola, Fla.	70.0	70.0	70.0	70.0
Peoria, Ill.	56.0	56.0	56.0	54.0
Pontiac, Mich.	55.0	55.0	55.0	55.0
San Antonio, Tex.	76.0	76.0	76.0	76.0
Sioux Falls, S.D.	55.0	55.0	55.0	55.0

TABLE 3

Summer Temperatures of Municipal Water Supplies for Various Cities Using Surface Water Sources

Location	Temp. at Main Outlet °F.			
	June	July	Aug.	Sept.
Atlanta, Ga.	78.1	83.5	79.5	77.8
Baltimore, Md.	61.0	66.0	70.0	64.0
Birmingham, Ala.	78.0	82.0	81.0	79.0
Boston, Mass.	68.3	74.3	73.4	69.4
Buffalo, N.Y.	62.0	71.0	73.0	66.0
Chicago, Ill.	55.4	68.0	69.4	62.5
Cincinnati, Ohio	76.0	82.0	81.0	77.0
Cleveland, Ohio	58.0	68.0	73.5	71.0
Detroit, Mich.	64.0	75.0	74.0	68.0
Kansas City, Mo.	84.0	93.0	91.0	85.0
Louisville, Ky.	77.0	82.0	82.0	77.0
Nashville, Tenn.	84.0	88.0	88.0	84.0
New Orleans, La.	86.0	89.0	90.0	90.0
Oakland, Calif.	59.0	62.0	64.0	64.0
Philadelphia, Pa.	71.0	79.0	77.0	72.0
Pittsburgh, Pa.	75.2	80.6	80.6	75.2
Sacramento, Calif.	70.7	70.7	80.6	77.0
St. Louis, Mo.	77.0	85.0	83.0	75.0
Washington, D.C.	43.0	67.0	73.0	75.0

that there was insufficient well water to meet the low temperature cooling water requirements, and the latter supply had to be augmented by refrigeration and a cooling tower. The estimated cost of the cooling tower equipment and the supplementary mechanical refrigeration to meet the plant requirements amounted to nearly half a million dollars. This condition was not due to the increased temperature of the water because of industrial wastes discharged into the supply; however, the incident is related here to indicate the financial phase of the cooling problem.

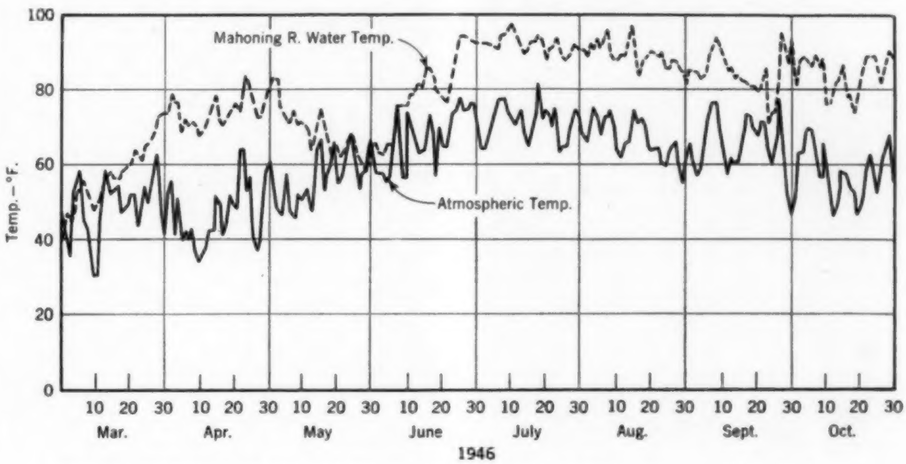


FIG. 1. Relation of Air and River Water Temp. in Youngstown (Ohio) Area

Effect of Water Quality

The more important impurities in water which affect its utility for cooling purposes are scale-forming constituents (hardness), suspended matter, dissolved corrosive gases, acids, oil or other organic matter and slime-forming organisms. Here again well water is usually superior to surface water because it contains less suspended matter, dissolved oxygen and micro-organisms. However, in some areas the deep well water is very hard and contains iron, manganese, fixed sulfides or, occasionally, ammonia, the latter two being very corrosive to certain metals and alloys.

Surface water supplies used once-through for cooling, or water recirculated over cooling towers, may introduce problems related to all of the undesirable impurities listed above. Suspended solids in the cooling water are especially objectionable when they lodge on heat exchanger surfaces, since such materials, when accompanied by bacterial slimes and corrosion products, cause marked loss in cooling efficiency and accelerated corrosive attack on both ferrous and nonferrous metals. Figures 2 and 3 illustrate respectively the condition of surface condensers when cooled by an untreated water and when cooled by a supply treated to prevent the deposition of solids.

The high temperatures in heat exchangers increase the rates of decomposition of organic compounds, slime growths and gas formation.

Treatment methods are available to eliminate or minimize the ill effects of

all of the impurities commonly encountered in underground, surface or recirculated water. Obviously, costs will limit the extent of treatment that is permissible and will dictate an arrangement of the water system to permit maximum re-use before discharge to waste.

Control of Corrosion and Scale

In an earlier paper (4) attention was directed to the difficulty of laying down a protective scale on tube surfaces when the cooling water supply was contaminated by slimes, algae and miscellaneous organic materials. The inhibiting effect of such pollutants is pictorially revealed in Fig. 4a and 4b. The specimen in Fig. 4a shows the corroded condition which occurred because of the failure to deposit calcium carbonate scale in the presence of organic inhibitors, while Fig. 4b shows a sample from a tube which has been completely protected by a thin, hard, dense and adherent calcium carbonate coating. The deposition of this type of protective coating can only be obtained when the saturation index has been properly maintained and when no organic inhibitors are present in the water supply. These conditions illustrate the need for minimizing the organic contaminants in water which is to be conditioned to deposit protective coatings for the prevention of corrosion in cooling water systems.

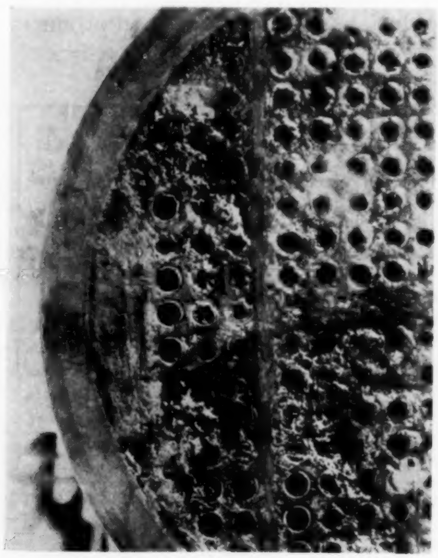


Fig. 2. Condenser Cooled by Untreated Water

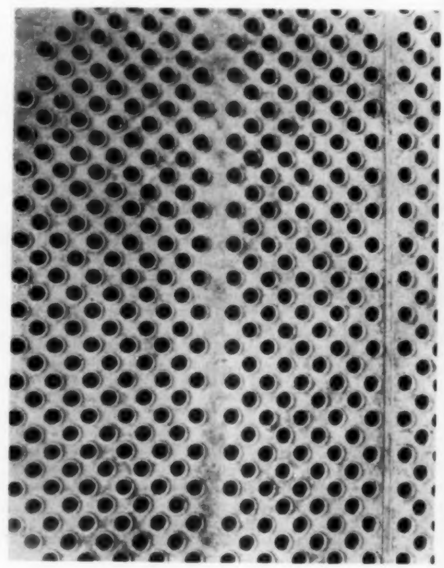


Fig. 3. Condenser Cooled by Treated Water

Process Water

As previously indicated, it is not possible in this paper to present a complete discussion of the requirements of the many water-using industries. This discussion is limited to a few of the more important ones to indicate the nature and extent of the problems encountered in these industries.

Water which is applied directly to the product must be treated selectively to meet the specific requirements of the particular product manufactured. Since the majority of manufactured products require different types of water, the characteristics of the raw water are not of prime importance except for their influence on the cost of treatment. It is obvious that the poorer the quality of the raw water, the more costly it will be to treat the supply.

Paper and Textile Manufacturing

Ordinarily, water from underground sources is preferred to surface water supplies which are subject to contamination, but the very high demand for water in the paper and textile industries frequently precludes the exclusive use of ground water because of the limited supply generally available from most water-bearing aquifers. In the larger plants, therefore, water from surface sources must be employed, and since these supplies are seldom suitable in their raw state, treatment is required.

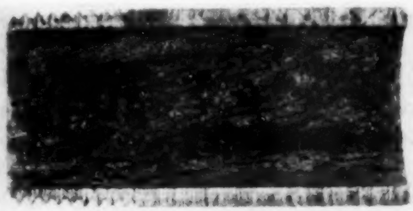


Fig. 4a. Corrosion Test Specimen

Fig. 4b. Corrosion Test Specimen

The most important water quality requirements in the paper and textile industry are freedom from color, turbidity and suspended matter. There are also limitations on the content of hardness, manganese and iron. Control of slime formations, algae growths and various micro-organisms is commonly necessary in paper mills, especially if the raw water is heavily polluted.

Water softening and the removal of color, suspended matter, iron and manganese are readily effected by standard treatment and filtration facilities. However, all water conditioning is detrimentally affected when the water is contaminated by domestic sewage and industrial wastes. High concentrations of soluble organic matter greatly retard coagulation of color or turbidity as well as the softening reactions of the lime and soda process. Difficulty has also been experienced in the removal of iron and manganese in the presence of certain types of organic material.

If reasonably soft water is available for use in the textile industry, softening may not be essential, but this is seldom the case. For instance, in the processing of cotton fabrics, the material is boiled with an alkali to remove certain constituents in the fabric, particularly waxes and similar products. If hard water is used, the alkali solution (usually soda) causes the formation of calcium and magnesium salts which are highly objectionable. It is particularly difficult to mercerize fabrics if hard water is used, because of the failure of adequate penetration of the dyes subsequently applied.

A few years ago widespread difficulty was experienced in one location in the textile and silk industries when a harder water supply was substituted for a relatively soft public water supply which had been treated to prevent corrosion by maintaining a high pH value. It was found that the hard water caused precipitation of salts in processing silk fibres and prevented the penetration of the weighing material into the fabric. Difficulty was also experienced in the woolen industry in the same area because of the detrimental effect of the hard water on some step in the processing of this material. The problem was overcome by reverting to the use of the original supply and selectively furnishing only certain industries with the hard water.

Pharmaceutical and Biological Requirements

Water entering pharmaceutical and biological products requires a higher degree of purification than is necessary in any other industry. Water for these purposes cannot be used satisfactorily as received from any of the ordinary sources available. Even with the most meticulous water conditioning operation involving clarification and softening, the water produced is still unsatisfactory for some of the more refined requirements in the industry in question.

Where water is to be used for the manufacture of serum, it must be "pyrogen-free." The term "pyrogen" is not widely recognized in the water works field, but it is used to define specific requirements in the pharmaceutical industry. Stedman's *Medical Dictionary* defines pyrogen as "an agent which causes a rise in temperature." It is probable that the pyrogens are complex bodies induced by certain types of microscopic organisms, or possibly the products of bacterial metabolism. Although the nature and character of pyrogens are still in the "twilight zone" of exact knowledge, much study and research is being conducted to establish the character of these products.

As the result of recent research in this field, certain pyrogenic products formed by micro-organisms have been concentrated in sufficient amounts to permit them to be analyzed. This work has shown that they contain phosphorus, but one authority states that they "probably do not contain nitrogen or proteins, as they are believed to be of the sugar family, i.e., carbohydrates." The art of recognizing and controlling pyrogens is now sufficiently advanced so that there is no longer any danger in preparing serums which contain these materials.

It has been demonstrated that simple distillation does not destroy pyrogens and that they are carried over with the stream or vapor and reappear in the condensate. In solution they withstand the ordinary sterilizing procedures, and although they may be present only in infinitesimal quantities, they are not detected by the usual forms of analysis. Even when present in minute quantities, pyrogens can cause considerable physiological upset when they enter the blood stream. This may occur upon the injection of improperly prepared serums. During the war considerable information was gained regarding the action of these materials, because of the extensive use of blood plasma transfusions.

The sources of pyrogens are not entirely known but are probably very widespread. They may be present both in the atmosphere and in water. Pyrogens, or the effect of pyrogens, can be

minimized or eliminated at high temperatures, and it is reported that when exposed to a temperature of 464° F., their ability to cause fever disappears. Because of the serious difficulties resulting from the presence of pyrogens in the manufacture of serum and antitoxins, extreme aseptic conditions must be maintained.

To assure pyrogen-free water, users of such supplies depend on triple distillation, and in some cases complete demineralization of the water by means of ion-exchange equipment is practiced prior to distillation. One serum manufacturer has advised that the pyrogen-free water must be kept hot, since if this is not done, the pyrogens are again formed. A special asbestos filter has been developed which is reported to remove these materials. In addition, many manufacturers treat the water in the stills with permanganate in order to destroy the pyrogens which otherwise would be carried over with the vapor.

To what extent the contamination of surface watercourses by domestic sewage or by miscellaneous industrial wastes increases the pyrogen content of the supply is not known, but it offers a fruitful field for research.

Treatment of Water for Steam Generation

During the past ten or more years, the specifications for the quality of water for boiler feed water use have become increasingly exacting. This has been brought about by the installation of boilers, designed to operate at high generating rates, which produce steam at greatly increased pressures and temperatures. A few years ago it was current practice to operate boilers in the range of 250–450 psi. At the present time a large number of units are installed which are operating at 1,000 psi.; several boilers are now in service, or are in the process of construction, which will operate at 2,500 psi. These conditions require a boiler feed water of high purity in order to avoid costly maintenance for repairs. Furthermore the large invest-

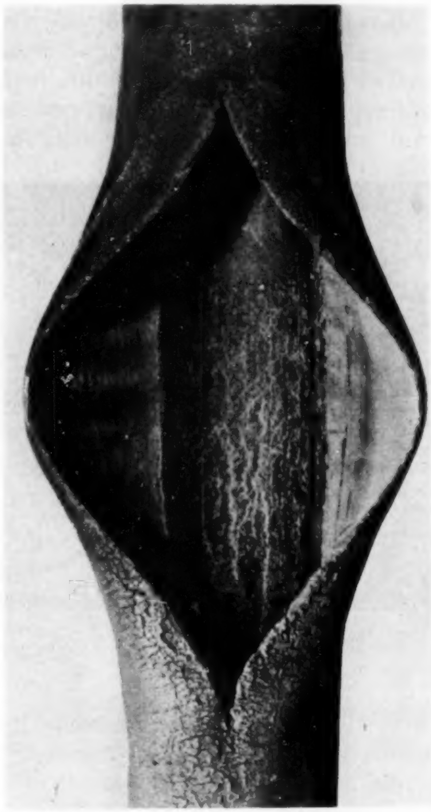


FIG. 5. Tube Failure Due to Analcite Scale

ment for this type of steam generating equipment demands a minimum of outage. It is now common practice to keep boilers in continuous service for a period of one to two years.

In central station practice employing steam turbines and surface condensers, very little new water or make-up is

used, since practically all of the steam is condensed and returned to the boilers as feed water. There is now a marked trend, however, toward the use of high-pressure steam plants in industrial establishments, and most of these require a large percentage of make-up due to the fact that large quantities of steam are consumed in process.

Because of these trends, the effect of sewage and industrial pollution upon surface supplies, which constitute most of the raw water used for steam generation, is becoming increasingly more important. Organic contaminations inhibiting softening reactions are highly objectionable, since the pollutants may reach the boilers where they decompose and form products which become entrained in the steam, thus resulting in operating and maintenance problems.

Fig. 6. Siliceous Deposits on Turbine Blading

Soluble silica is particularly detrimental, for it tends to form dense, hard scale on heating surfaces. This is true even when the silica is present in extremely low concentrations. There are many boiler scales of this type, the most objectionable ones being of the analcite series which, when deposited on metal surfaces receiving high heat input, cause damage in a short time. Boiler tube failure caused by this type of overheating due to scale is illustrated in Fig. 5.

One of the most serious problems now facing the operation of central stations and industrial plants where high-pressure boilers are employed is the deposition of silica on the blading of steam turbines (Fig. 6). No solution to this problem has yet been found and extensive research is under way in an effort to develop corrective measures. The siliceous material may be deposited in several forms. A list of the products is given in Table 4. These compounds, which are largely pure silica, are extremely difficult to remove from the blades. When the formations accumulate in sufficient amount there is considerable loss of capacity in the generating unit. If this condition reaches a critical stage, the siliceous deposits must be removed by backwashing with wet steam and caustic soda, or the unit must be taken out of service, completely dismantled and the formations removed by blasting with fly ash or other materials.

TABLE 4

X-Ray Identification of Deposits Removed From Blading of Steam Turbines

Compound	Mineral Name	Formula
Calcium carbonate	Calcite	$CaCO_3$
Calcium carbonate	Aragonite	$CaCO_3$
Calcium aluminate		$3CaO \cdot Al_2O_3 \cdot 6H_2O$
Calcium phosphate	Phosphate	$Ca_3P_2O_8 \cdot H_2O$
Magnesium hydroxide	Brucite	$Mg(OH)_2$
Copper sulfite	Chalcocite	Cu_2S
Nickel oxide	Bunsenite	NiO
Silicon oxide	Quartz	SiO_2
Silicon oxide	Cristobalite	SiO_2
Silicon oxide	Opal	SiO_2
Sodium sulfate	Thernadite	$Na_2SO_4(V)$
Sodium-carbonate-sulfate	Burkeite	$Na_2CO_3 \cdot 2Na_2SO_4$
Sodium chloride	Halite	$NaCl$

All surface water supplies, in their natural condition, contain some silica. Difficulty from this constituent may therefore exist regardless of industrial or sewage contamination. In a number of cases investigated by the author, however, the condition of the deposition of silica in boilers and on turbine blading has been magnified as a result of contamination from waste products. The effect of such pollution is not ordinarily recognized except by those specializing in this field. However, these losses translated into dollar values involve great sums of money, and they are therefore of sufficient importance to demand recognition and corrective measures.

Because of the complexity of the subject, the foregoing discussion has been limited to general water quality requirements for boiler feed water and the effect of pollution on the quality of supplies used for this purpose. The conditions and examples cited serve to illustrate the need for careful investigation and planning prior to the installation of high-pressure boilers and auxiliary equipment.

Observations of Ground Water

The exhaustion of underground waters by concentration of industries depending on such supplies is having marked repercussions on the industrial growth and future development in many sections. In the Texas City, Tex., area, during the past ten years, the elevation of ground water has dropped and is continuing to fall at a rapid rate. The water level in deep wells is now receding at a rate of 23 ft. per year, while shallow wells have lost 16 to 18 ft. per year for several years. This condition has resulted in dewatering the sands to such an extent that at some points within this area the elevation of the land has dropped as much as 2 ft.

During the war period, when a heavy overdraft was imposed upon the water-bearing aquifers in the Louisville area because of the high concentration of industries (especially synthetic rubber plants), a serious condition arose. A number of emergency measures were required to insure the continuous operation of these plants because of their great importance to the war effort. Similar conditions are occurring in southern California, Texas, Florida and other locations. These problems clearly demonstrate the need for curtailing the withdrawal of underground waters and the need for increasing the use of surface supplies to meet industry's requirements. It must be obvious that dependence on surface supplies requires a minimum of pollution loading to avoid serious operational problems in meeting the industrial and commercial requirements.

Concerning the exhaustion of wells in certain areas, some relief may be effected by recharging the aquifers with cold treated water during the winter months and using the cold water supply thus stored during the warm weather. Such replenishment of the underground supplies has been advocated by the U.S. Geological Survey for a number of areas where the underground water supplies are affected critically.

Replenishment or recharging in this way has merit but it is imperative to use only water which is safe from a sanitary standpoint and which will be chemically compatible with the underground water so as not to affect adversely either the well supply or the water-bearing formation from which the water is drawn. This operation requires a well-planned program and

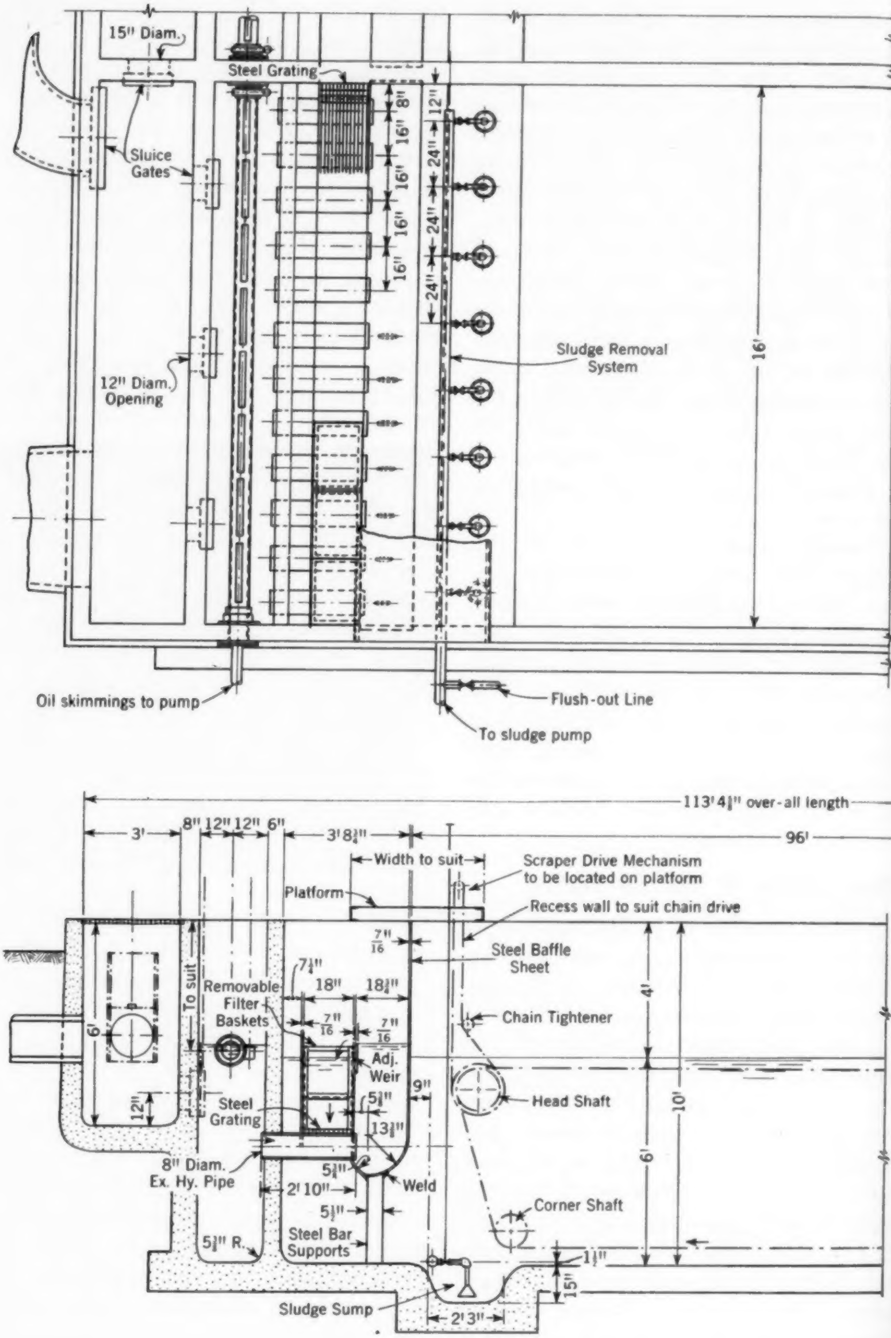
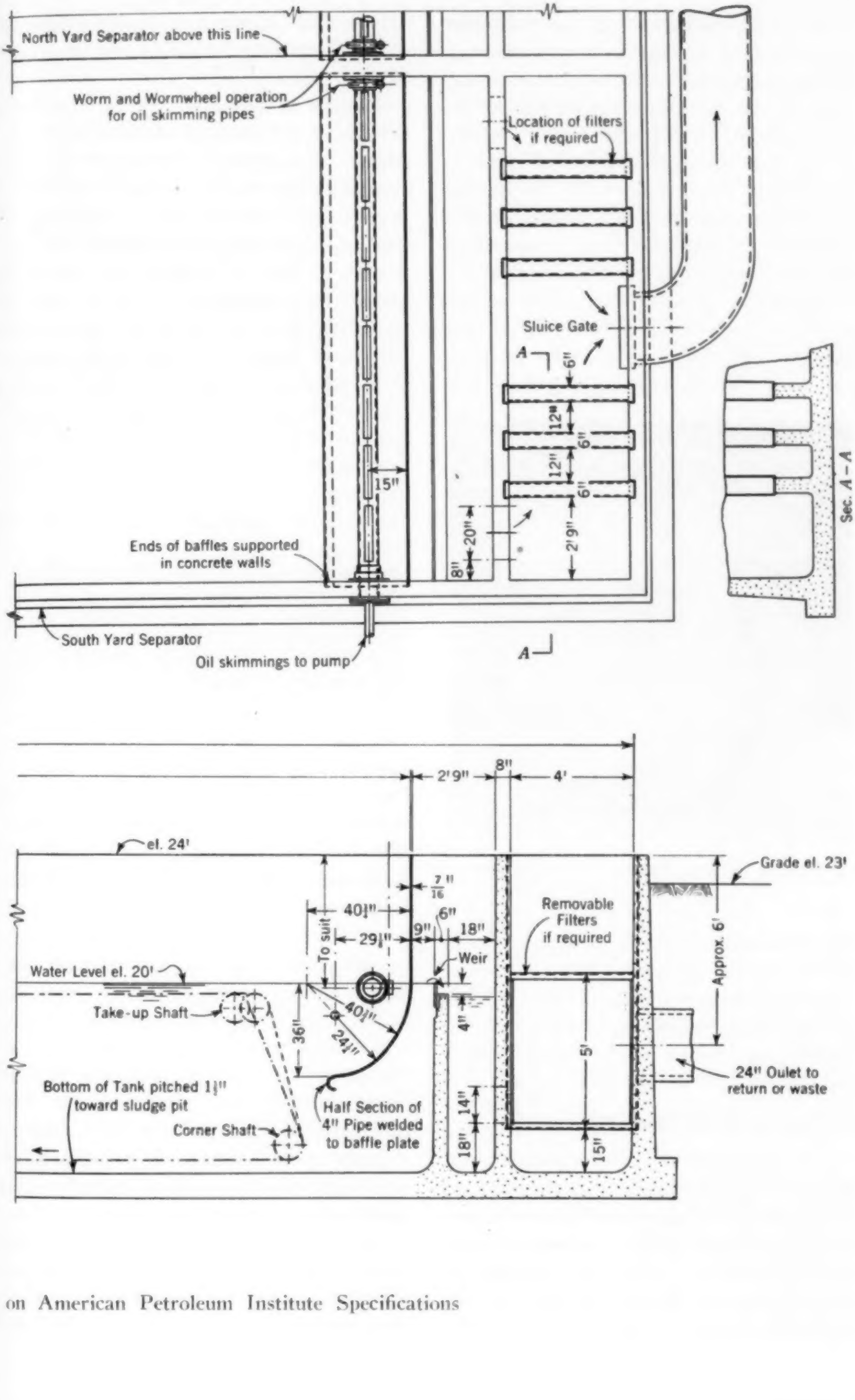


FIG. 7. Design of Gravity Oil Separator Based



on American Petroleum Institute Specifications

careful consideration of the economic and practical aspects to assure success. It has potential merit, since in many cases it may minimize or correct severe cold ground water shortages. Often it can be justified from the savings which can be effected by providing continuous use of cold ground water in warm weather, thereby eliminating the need for installing refrigeration.

Favorable results can only be secured by selective recharging of the aquifer with cold water. In at least one case the underground water sup-

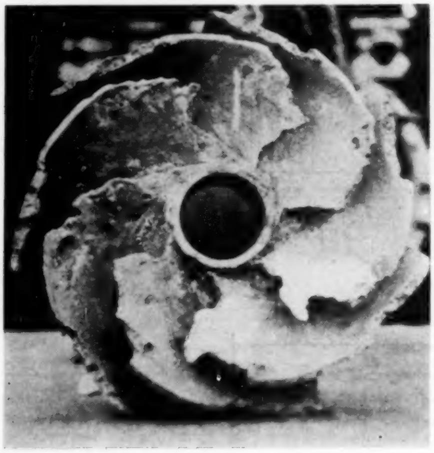


FIG. 8. Pump Runner Damaged by Aggressive Water

ply was replenished by pumping warm water into the ground. In a short time the temperature of the entire underground water supply increased, and the recharging had to be curtailed because the supply lost its thermal value.

Influence of Stream Pollution

The pollution of surface water supply sources has become a problem of major magnitude, and legislative bodies have responded with a variety of control measures. Pollution loading on streams has a direct bearing on the type and design of water conditioning plants and on the investment required for the treating facilities and the cost of operation.

Industrial management has not fully realized the import of stream pollution. Many processing difficulties due to contaminants in the water could have been relieved by adequate planning in the selection and treatment of the raw water. Lack of intelligent planning about the availability of water and its pollution loading has been responsible for heavy financial losses by the industries affected. Mutual understanding and cooperation by groups of industries whose waste products, jointly or separately, detrimentally affect others are urgently required. If cooperative planning is properly instrumented, it will bear fruitful results to all concerned.

Oil Contamination

Practically all surface waters receiving industrial wastes are contaminated by oil to some degree. In areas where petroleum refineries are located, contamination may be fairly extensive. Oil and grease contaminants are contributed also by vegetable oil processing plants, wool scouring operations, domestic sewage and other sources. Oily water may retard corrosion of metal in some instances, but waters contaminated by oil or grease are highly objectionable when used as cooling water for heat exchangers, surface condensers and similar types of equipment. The free oil present can fairly readily be removed by adequately designed and operated treating systems, but when oil is present as an emulsion or in combined form, it may pass through treatment plants.

No oil should be present in boiler feed water. (Performance guarantees for modern boilers stipulate that oil in the concentrated boiler water shall not

exceed 7 ppm.) Serious damage has resulted from only a few parts per million of oil in water fed to high-pressure boilers. When oil is present in the feed water, it forms deposits on the boiler tube surfaces and prevents proper heat transfer, thus causing overheating and final failure of the metal.

The increasing demand for reduction of the amount of oil in waste waters is requiring the installation of oil removal systems not previously considered necessary. The type of equipment which has been most extensively used in the past, and which is still the most practical design to employ for this purpose, is that proposed by the American Petroleum Institute. The design of this equipment is shown in Figure 7.

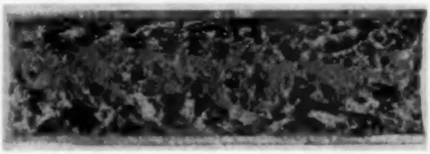


FIG. 9a. Corroded Pipeline Section

The A.P.I. separator consists of two basins connected in series which are designed to effect gravity separation of oil from water with provision of mechanical equipment for removal of both separated oil and deposited solids. The basic features of design are directed toward the agglomeration of small droplets of oil and the maintenance of a straight-line flow of liquid. This minimizes the turbulence, which might otherwise interfere with the gradual rise or fall of particles whose specific gravity approaches that of the water in which they are carried. Units of this kind, when properly designed and operated, are quite effective in removing free oil but cannot be depended upon to remove oil in emulsified form.

In a recent investigation made by the author, it was found that at certain periods of operation the oil content leaving a standard A.P.I. separator was higher than could be considered satisfactory. A study in the plant showed that the oily wastes delivered from one operation were in a highly emulsified form, and this material, although relatively small in volume (in proportion to the total waste), resulted in poor operation of the A.P.I. separator. The problem was solved by treating the oily emulsion separately.

The treatment for breaking the emulsion consisted of coagulation with lime and an iron salt, and the subsequent removal of demulsified and suspended oils by means of a Dorr clarifier. Through the operation of the combined systems, the refinery in question is now

FIG. 9b. Corroded Pipeline Section (Rust Tubercles Removed)

delivering, at all times, an effluent with an oil content not exceeding a range of 5–10 ppm.

It is difficult to establish any maximum limit to the quantity of oil which should be permitted to discharge into a surface water supply. It is practically impossible to treat the waste water from a refinery or similar oil-producing industry so that no oil will escape. Moreover, a fixed arbitrary standard may not be practical or reasonable. A fair and workable limit to be imposed on oil content must take into account the local conditions and an evaluation of the capacity of the receiving body of water to destroy or dissipate the oil which will be added. It is the author's belief that each case should be judged on its own merits and

Fig. 10. Corroded Trap Element

with due regard to the rights and requirements of all parties using the water jointly.

Corrosive Contaminants

The presence of acid wastes in water used by industry results in the rapid corrosion and destruction of pumps, heat exchangers and piping systems. In large plants such corrosion often involves many costly replacements. These conditions can be the result of inorganic acids or the decomposition of organic compounds. Figure 8 shows

the attack on the runners of a cast-iron pump. The action of corrosive cooling water on an unprotected steel pipeline, in service approximately three years, is illustrated in Fig. 9a. In Fig. 9b, the same section is shown with the rust tubercles removed, and the general pitting of the metal may be noted. The corrosive attack on the piping system of the plant could have been minimized by preventing the highly acid wastes from the plant of an adjacent industry from reaching the stream.

Ammoniacal contaminants in fairly dilute solution do not attack ferrous metal but may rapidly attack copper. When ammoniacal solutions are in contact with copper, a complex cuprous-ammonium ion is formed. The oxides of this ion are soluble and do not form a protective coating, and the metal is rapidly corroded and destroyed. Not only is copper attacked by ammonium salts, but many of the copper alloys are affected also. Yellow brass (Muntz metal) is rapidly dezincified when in contact with ammonia, and more resistant materials, such as Admiralty metal and other higher grade alloys, are rapidly corroded. The aggressiveness of such an attack is illustrated in Fig. 10. This is an enlarged view of a brass control element in a steam trap which was completely destroyed by corrosion in about three years because of the accumulation of ammonia released by the steam used for heating.

Heavy financial losses due to condenser tube failures have occurred, and are still being experienced, because of the presence of ammonia and amino acids in water circulated through condensers and through miscellaneous heat-exchange apparatus in central power stations and other plants.

High ammonia content in water is often the result of contamination with domestic sewage, gas-house wastes or coke-oven effluents. Waste from certain chemical plants often contains high concentrations of ammoniacal products. It is not possible to establish maximum limits for such constituents below which no difficulty will be experienced. Correction of the trouble rests largely on avoiding the discharge of high concentrations of such wastes into the watercourse and on the use of materials by designers and operators which will afford resistance against corrosive attack by the compounds present. Free residual chlorination can be used to remove ammonia and eliminate its attack on brass and copper; the suitability of such measures rests on the quantity of ammonia present and the resulting cost of treatment.

The most economical and intelligent approach for avoiding the corrosive attack on metal is to control the discharge of the wastes into waterways which are subsequently to be used by others. Mutual cooperation and understanding among industries should do much to relieve the existing stream pollution problems of this type.

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Design Standards for Steel Water Pipe

By Russell E. Barnard

A paper presented on May 7, 1946, at the Annual Conference, St. Louis, by Russell E. Barnard, Chairman, Tech. Standards Committee of the Steel Water Pipe Manufacturers Technical Advisory Committee; and Advisory Engr., Welded Pipe Sales Div., Armco Drainage and Metal Products, Inc., Middletown, Ohio.

STEEL water pipe has been designed in many ways and according to different standards. Site location, installation and operating conditions, and personal preference have largely determined the practices which were followed.

The purpose of this paper is to present in convenient form certain design data most urgently needed by engineers designing steel water pipelines. Only practical usable data is given. The size range covered is 6 to 36 in. inclusive.

Engineering theories may be referred to in the paper but are not explained in detail. Only the results of calculations are given, together with the basic data which produced the results. The references listed provide additional information for those who wish to consult them.

Uses of Steel Pipe

Steel water pipe meeting the requirements of the A.W.W.A. Standard Specifications 7A.3 (1) and 7A.4 (2) is satisfactory for the following services:

1. Supply lines
2. Equalizing mains
3. Force mains
4. Underwater river crossings
5. Bridge crossings
6. Swamp or marsh crossings
7. Water purification plants
8. Pump station piping
   - 8a. Water lines
   - 8b. Steam lines (pressures of 250 psi. or less)
9. Sewage disposal lines
10. Pressure sewers
11. Storm sewers
12. Water well casing

Depending upon local conditions and preference, steel pipe may or may not be used in distribution systems, or where there will subsequently be required a great number of service taps or small connections.

Determining Size of Steel Pipe Supply Lines

A theoretical treatment of the subject of hydraulics is not within the scope of this paper. Only phases which have a direct significance will be discussed. Methods of determining the actual flow in pipelines are still a subject of discussion. Formulas and formula constants now used are still being investigated and improvements are being sought. The data here presented permit the engineer conveniently to study the theoretical flow capacity of a

TABLE 1

Theoretical Head Corresponding to Given Velocity

Velocity *fps.*	Head *ft.*	Velocity *fps.*	Head *ft.*
1	0.02	16	4.0
2	0.06	18	5.0
3	0.14	20	6.2
4	0.25	22	7.5
5	0.39	24	9.0
6	0.56	26	10.5
7	0.76	28	12.2
8	1.0	30	14.0
9	1.3	32	15.9
10	1.6	34	18.0
12	2.2	36	20.1
14	3.0	38	22.4

TABLE 2

Hazen-Williams Coefficients for Pipe With Various Interior Surfaces

Type of Pipe or Interior Surface	Avg. *C*
New tar-coated cast iron	
16-in. and larger (supply and transmission mains)	135*
Smaller than 16-in. (distribution mains)†	125*
Cement lining (hand applied)	136‡
Cement lining (centrifugally applied)	150‡
Coal-tar enamel (centrifugally applied)	
16-in. and larger (supply and transmission mains)	155*
Smaller than 16-in. (distribution mains)†	145*

* Based on nominal diameter.
† Allowance included for tees, valves, bends, corporation cocks and so on.
‡ Based on net diameter.

TABLE 3

Multiplying Factors Corresponding to Various Values of C *in Hazen-Williams Formula**

Values of *C*	160	155	150	145	140	130	120	110	100	90	80	60	40
Base *C* = 150 (Use with Fig. 1)													
Relative discharge and velocity for given loss of head	1.067	1.033	1.000	0.967	0.933	0.867	0.800	0.733	0.667	0.600	0.533	0.400	0.267
Relative loss of head for given discharge	0.887	0.941	1.000	1.065	1.136	1.297	1.511	1.775	2.117	2.573	3.199	5.447	11.533
Base *C* = 130													
Relative discharge and velocity for given loss of head	1.231	1.192	1.154	1.115	1.077	1.000	0.923	0.846	0.769	0.692	0.615	0.462	0.308
Relative loss of head for given discharge	0.681	0.722	0.768	0.817	0.872	1.000	1.160	1.362	1.625	1.972	2.455	4.180	8.850
Base *C* = 100													
Relative discharge and velocity for given loss of head	1.600	1.550	1.500	1.450	1.400	1.300	1.200	1.100	1.000	0.900	0.800	0.600	0.400
Relative loss of head for given discharge	0.419	0.445	0.472	0.503	0.537	0.615	0.714	0.838	1.000	1.215	1.511	2.574	5.447

* Multiplying factors are shown for determining velocity, discharge and loss of head corresponding to other values of the coefficient *C* when tables or charts are available giving figures based on *C* = 150, *C* = 130 or *C* = 100. Comparison of discharge and friction losses in old and new pipe as well as in pipe of different materials is also easily made from any table or chart based on one of the three values of *C* just mentioned. For instance, if a new pipe of a given material has a coefficient of 150—and the discharge is found from a table or chart based on *C* = 150 (Fig. 1)—then another pipe for which *C* = 130 will carry 0.867 times as much water with the same friction loss or, if carrying the same amount of water, will show a friction loss 1.297 times that of the first pipe.

given pipeline as he arbitrarily changes the formula constants.

Flow Through Straight Pipe

The quantity of water which will pass through any given pipe is determined by the head or pressure producing flow, the diameter and length of the pipe, the condition of the pipe interior (whether smooth or rough), the

TABLE 4

Slope Conversions

1 Fall per Foot of Pipe *ft.*	2 Grade of Pipe %	3 Drop per 1,000 ft. of Pipe *ft.*	4 Drop per Mile of Pipe *ft.*	5 Length of Pipe in 1-ft. Drop *ft.*
0.00005	0.005	0.05	0.264	20,000.0
0.0001	0.01	0.10	0.528	10,000.0
0.0002	0.02	0.20	1.056	5,000.0
0.0003	0.03	0.30	1.584	3,330.0
0.0004	0.04	0.40	2.112	2,500.0
0.0005	0.05	0.50	2.640	2,000.0
0.0006	0.06	0.60	3.168	1,666.7
0.0007	0.07	0.70	3.696	1,428.6
0.0008	0.08	0.80	4.224	1,250.0
0.0009	0.09	0.90	4.752	1,111.1
0.001	0.10	1.00	5.280	1,000.0
0.002	0.20	2.00	10.56	500.0
0.003	0.30	3.00	15.84	333.0
0.004	0.40	4.00	21.12	250.0
0.005	0.50	5.00	26.40	200 0
0.006	0.60	6.00	31.68	166.7
0.007	0.70	7.00	36.96	142.9
0.008	0.80	8.00	42.24	125.0
0.009	0.90	9.00	47.52	111.1
0.01	1.00	10.00	52.80	100.0
0.02	2.00	20.00	105.60	50.0
0.03	3.00	30.00	158.40	33.3
0.04	4.00	40.00	211.20	25.0
0.05	5.01	50.00	264.00	20.0
0.06	6.01	60.00	316.80	16.7
0.07	7.02	70.00	369.6	14.3
0.08	8.03	80.00	422.4	12.5
0.09	9.04	90.00	475.2	11.1
0.10	10.05	100.00	528.0	10.0
0.12	12.09	120.00	636.6	8.3

number and the abruptness of bends or elbows and the presence of valves or other accessories incorporated in the line.

The total head or pressure producing flow may be divided into four parts:

1. Velocity head
2. Loss of head at entrance
3. Loss of head through friction
4. Minor losses due to elbows, fittings, valves and the like.

In long lines the sum of velocity head and loss at the entrance ordinarily does not exceed 1 ft. These losses become highly important considerations, however, in short lines with high velocity. Ordinary tables and charts show-

TABLE 5

Flow Equivalents

mgd.	*gpm.*	*cfs.*	*mgd.*	*gpm.*	*cfs.*
1	694	1.55	36	25,000	55.73
2	1,389	3.09	37	25,694	57.28
3	2,083	4.64	38	26,389	58.82
4	2,778	6.19	39	27,083	60.37
5	3,472	7.74	40	27,778	61.92
6	4,167	9.28	42	29,167	65.02
7	4,861	10.83	44	30,556	68.11
8	5,556	12.38	46	31,944	71.21
9	6,250	13.93	48	33,333	74.31
10	6,944	15.48	50	34,722	77.40
11	7,639	17.02	52	36,111	80.50
12	8,333	18.57	54	37,500	83.60
13	9,028	20.12	56	38,889	86.69
14	9,722	21.67	58	40,278	89.79
15	10,417	23.22	60	41,667	92.88
16	11,111	24.77	62	43,056	95.98
17	11,806	26.31	64	44,444	99.08
18	12,500	27.86	66	45,833	102.17
19	13,194	29.41	68	47,222	105.27
20	13,889	30.96	70	48,611	108.37
21	14,583	32.51	72	50,000	111.46
22	15,278	34.05	74	51,389	114.56
23	15,972	35.60	76	52,778	117.65
24	16,667	37.15	78	54,167	120.75
25	17,361	38.70	80	55,556	123.85
26	18,056	40.25	82	56,944	126.94
27	18,750	41.80	84	58,333	130.04
28	19,444	43.34	86	59,722	133.14
29	20,139	44.89	88	61,111	136.23
30	20,833	46.44	90	62,500	139.33
31	21,528	47.99	92	63,889	142.43
32	22,222	49.54	94	65,278	145.52
33	22,917	51.08	96	66,667	148.62
34	23,611	52.63	98	68,056	151.71
35	24,306	54.18	100	69,444	154.81

ing flow of water in pipe give only the loss due to friction, which, in long lines, is most important. Losses of head due to bends and obstructions are classed as minor and are frequently ignored. However, in any given instance, it is best to consider all losses, since their importance varies in different cases.

In the final correct solution to a flow problem (which must usually be found by the trial-and-error method) the sum of all losses must equal the available head producing flow.

Entrance head loss is the head required to overcome the resistance at the entrance to the pipe. It is always less than the velocity head. When the conditions are not specified, it is usually

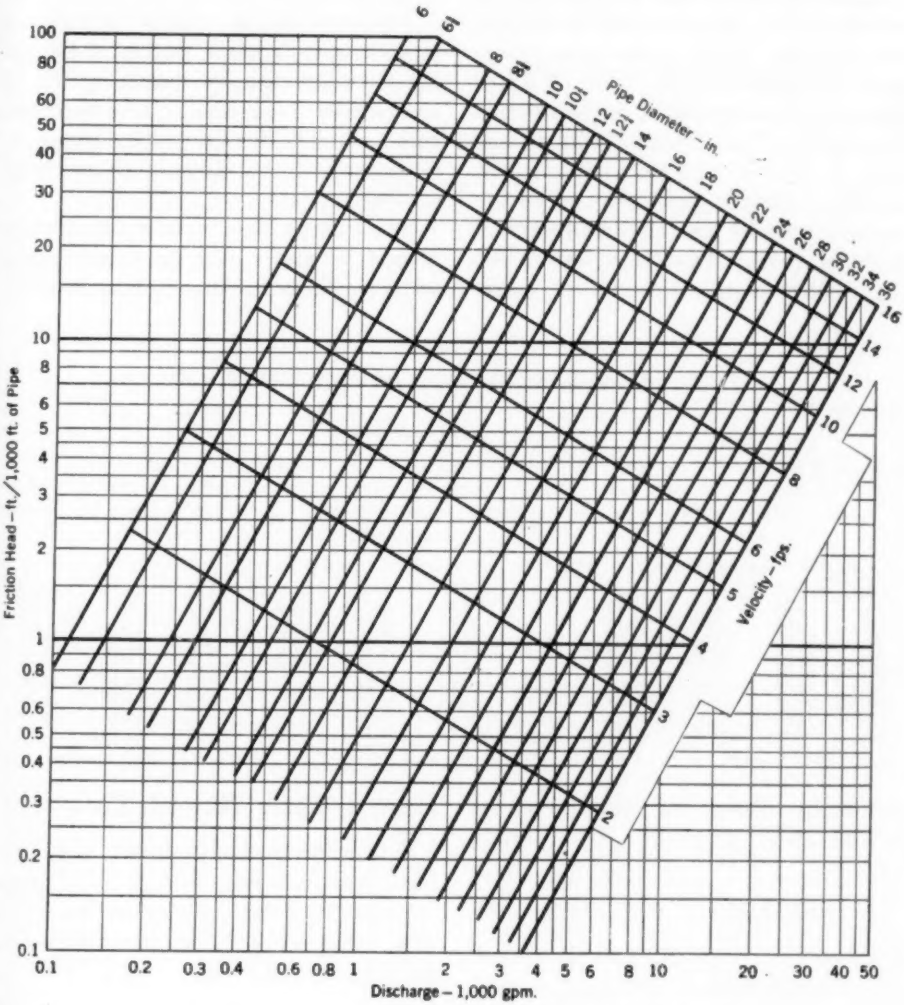

FIG. 1. Graph of Hazen-Williams Formula for $C = 150$

Velocity head is defined as the height through which a body must fall in a vacuum to acquire the velocity with which the water flows in the pipe. Numerical values are given in Table 1.

taken as being equal to one-half the velocity head. This is the condition for a sharp-edged entrance. Safe values of the ordinary entrance head loss may therefore be found from Table 1 by

taking 0.5 of the velocity head corresponding to the velocity in the pipeline. Head loses for other than sharp-edged entrances may be found in treatises on hydraulics.

Loss of head through friction may be determined by using one of the numerous formulas which have been developed for calculating the flow of water through closed conduits based on this factor only. The Hazen-Williams formula is widely used by hydraulic engineers. Since coefficients covering various types of materials and various kinds of linings have been developed and related to this formula, it is exceptionally useful for comparison as well as design purposes. The formula is:

$$v = 1.318\ C\ r^{0.63}\ s^{0.54}$$

in which C is the coefficient dependent upon the roughness of the pipe interior, r is the hydraulic radius in feet and s is the sine of the slope of hydraulic gradient, or the loss of head in feet per foot of pipe.

Table 2 gives coefficients for the Hazen-Williams formula based upon actual hydraulic tests on pipelines of various materials, both without any lining and with lining of cement or coal-tar enamel (3).

A graph for solving the Hazen-Williams formula when C equals 150 is given in Fig. 1.

The multiplying factors in Table 3 provide a convenient means of changing the flow capacity shown by Fig. 1 to the flow for values of C other than 150. Flow tables or graphs based on C values of 100 or 130 may likewise be modified.

The information contained in Tables 4, 5, 6, 7 and 8 will be found useful when making calculations in hydraulics.

TABLE 6

Pressure in Pounds per Square Inch for Given Heads of Water

Head *ft.*	Additional Units 0	+1	+2	+3	+4	+5	+6	+7	+8	+9
	Pressure—*psi.*									
0	—	0.43	0.87	1.30	1.73	2.16	2.60	3.03	3.46	3.90
10	4.33	4.76	5.20	5.63	6.06	6.49	6.93	7.36	7.79	8.23
20	8.66	9.09	9.53	9.96	10.39	10.82	11.26	11.69	12.12	12.56
30	12.99	13.42	13.86	14.29	14.72	15.15	15.59	16.02	16.45	16.89
40	17.32	17.75	18.19	18.62	19.05	19.48	19.92	20.35	20.78	21.22
50	21.65	22.08	22.52	22.95	23.38	23.81	24.25	24.68	25.11	25.55
60	25.98	26.41	26.85	27.28	27.71	28.14	28.58	29.01	29.44	29.88
70	30.31	30.74	31.18	31.61	32.04	32.47	32.91	33.34	33.77	34.21
80	34.64	35.07	35.51	35.94	36.37	36.80	37.24	37.67	38.10	38.54
90	38.97	39.40	39.84	40.27	40.70	41.13	41.57	42.00	42.43	42.87

Flow of Water Through Fittings

Experiments have shown that the head loss in bends, fittings and valves is related to the velocity of flow and pipe diameter in a manner similar to that in straight pipe. Since this is true, it is possible to determine the theoretical length of a piece of straight pipe in which the loss of head due to friction would be the same as for some fitting. This method is called that of "equivalent lengths." It is recognized by several authorities (4, 5).

When using this plan, determine the actual length of the pipeline by adding to the centerline length of straight pipe in the line the distance on centerline through all the fittings. Then total the "equivalent length in pipe diameters" for all the fittings. This accounts for the *extra* friction in the fittings. Convert this number of pipe diameters to the equivalent length distance by multiplying by the pipe diameter in feet. Add this distance to the actual length of the pipe. The total friction in this theoretically elongated line of straight pipe, calculated using the applicable unit loss per foot, is assumed to equal that in the shorter pipeline which contains the fittings.

Table 9 shows length equivalents which are reasonably correct. The actual length of pipeline containing fittings should be increased by the equivalent lengths indicated in Table 9 before determining the slope of the hydraulic gradient.

It is not usually necessary to make allowance for minor losses (except entrance) in ordinary pipelines containing no fittings. Such losses as occur at the slight deflections permissible in the standard joints are accounted for by the flow formula itself.

Standard Steel Pipe Sizes

After hydraulic calculations have been made, the size to be used may be selected from Table 10.

Electric Power Pumping Costs

The cost of pumping water through pipe may be obtained conveniently with the aid of Fig. 2.

Chart values are based on a 75 per cent over-all efficiency of the pumping unit. For other efficiencies multiply horsepower or cost read from the chart

TABLE 7

Water Head Corresponding to Given Pressure

Pressure *psi.*	Additional Units									
	0	+1	+2	+3	+4	+5	+6	+7	+8	+9
	Head—*ft.*									
0	—	2.3	4.6	6.9	9.2	11.5	13.9	16.2	18.5	20.8
10	23.1	25.4	27.7	30.0	32.3	34.6	36.9	39.3	41.6	43.9
20	46.2	48.5	50.8	53.1	55.4	57.7	60.0	62.4	64.7	67.0
30	69.3	71.6	73.9	76.2	78.5	80.8	83.1	85.4	87.8	90.1
40	92.4	94.7	97.0	99.3	101.6	103.9	106.2	108.5	110.8	113.2
50	115.5	117.8	120.1	122.4	124.7	127.0	129.3	131.6	133.9	136.3
60	138.6	140.9	143.2	145.5	147.8	150.1	152.4	154.7	157.0	159.3
70	161.7	164.0	166.3	168.6	170.9	173.2	175.5	177.8	180.1	182.4
80	184.8	187.1	189.4	191.7	194.0	196.3	198.6	200.9	203.2	205.5
90	207.9	210.2	212.5	214.8	217.1	219.4	221.7	224.0	226.3	228.6

TABLE 8

Pressure Equivalents

Mercury *in.*	Water *in.*	*psi.*	Mercury *in.*	Water *in.*	*psi.*
1	13.6	0.49	13	176.8	6.38
2	27.2	0.98	14	190.4	6.87
3	40.8	1.47	15	204.0	7.36
4	54.4	1.96	16	217.6	7.85
5	68.0	2.45	17	231.2	8.34
6	81.6	2.94	18	244.8	8.83
7	95.2	3.44	20	272.0	9.82
8	108.8	3.93	22	299.2	10.80
9	122.4	4.42	24	326.4	11.78
10	136.0	4.91	26	353.6	12.76
11	149.6	5.40	28	380.8	13.74
12	163.2	5.89	30	408.0	14.72

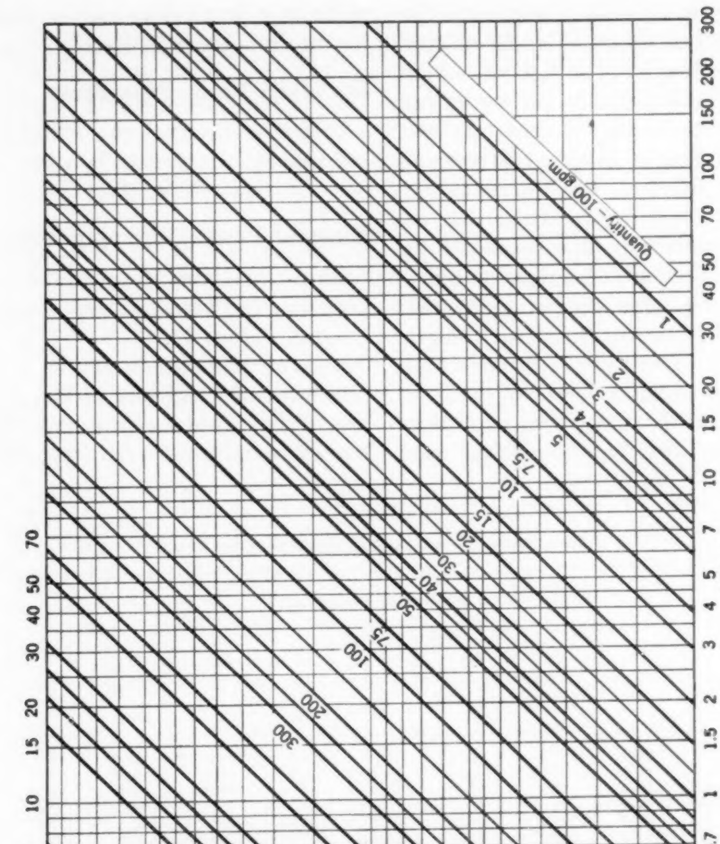

FIG. 2. Electric Power Pumping Costs

TABLE 9

Length of Straight Pipe Equivalent to Given Fittings, Based on Equal Friction Losses

Type of Fitting	Approximate Length Equivalent in Pipe Diameters
Miter elbows	
$22\frac{1}{2}°$ 2 piece	4
30° 2 piece	7
45° 2 piece	15
45° 3 piece	10
60° 2 piece	25
60° 3 piece	15
90° 2 piece	65
90° 3 piece	25
90° 4 piece	15
Tee	
Flow through run	20
Flow side outlet to run; or run to side outlet	
No throat	65
With throat	45
Lateral	45
Sudden contraction	
Ratio of inlet diam. to outlet diam.:	
4 to 1	14*
2 to 1	11*
4 to 3	7*
Sudden enlargement	
Ratio of inlet diam. to outlet diam.:	
1 to 4	32*
1 to 2	20*
3 to 4	7*

Type of Fitting	Approximate Length Equivalent in Pipe Diameters
Reducer	
$\frac{1}{4}$ reduction	26*
$\frac{1}{2}$ reduction	32*
Pipe entrance in concrete wall	
Ordinary square corner	16
Converging cone (apex angle 5–10°)	6
Pipe bends (smooth 90°, not mitered)	
Ratio of radius of bend to diam. of pipe:	
1	18
2	9
3	8
4	7
5	8
6	9
8	12
10	14
12	16
14	17
16	18
18	18
20	18
Gate Valve	
Fully open	7
$\frac{1}{4}$ closed	40
$\frac{1}{2}$ closed	200
$\frac{3}{4}$ closed	850
Swing Check Valve	
Fully open	80

* Figures apply to the smaller diameter.

by 0.75 and divide that result by the desired efficiency expressed as a decimal. Power cost is taken at 1¢ per kilowatt-hour. Multiply chart cost by actual kilowatt-hour cost to obtain pumping cost in any given instance.

The diagonal lines at the left of the chart have the following significance: line *A*—cost of pumping 1,000 hours; line *B*—cost of pumping 365 days at 24 hours per day; line *C*—cost of pumping 365 days at 12 hours per day; line *D*—cost of pumping 365 days at 8 hours per day; line *E*—cost of pumping 300 days at 24 hours per day; line *F*—cost of pumping 300 days at 12 hours per day; and line *G*—cost of pumping 300 days at 8 hours per day.

Use the chart by entering the diagram at the bottom of the vertical line corresponding to the total pump-

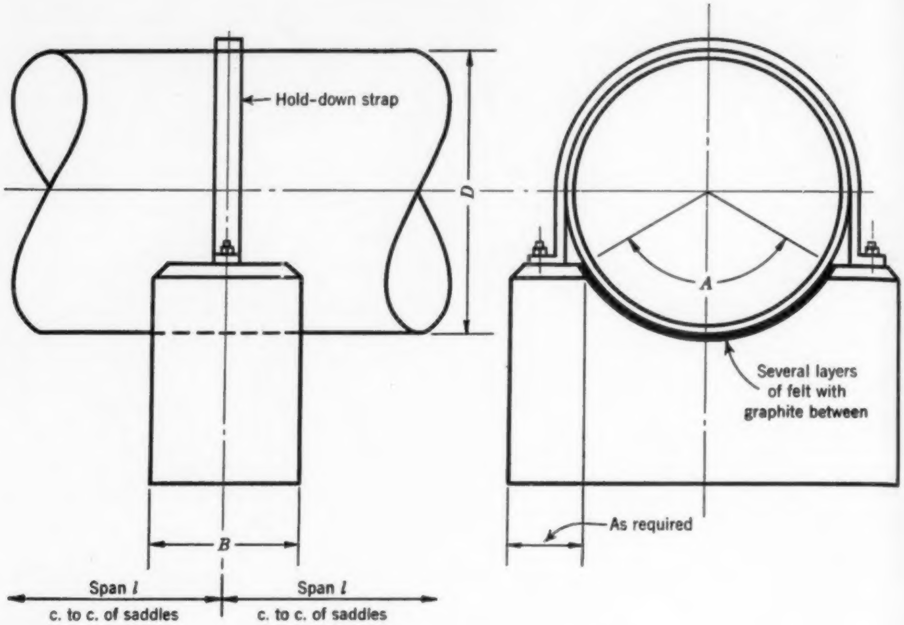

FIG. 3. Details of Concrete Saddles

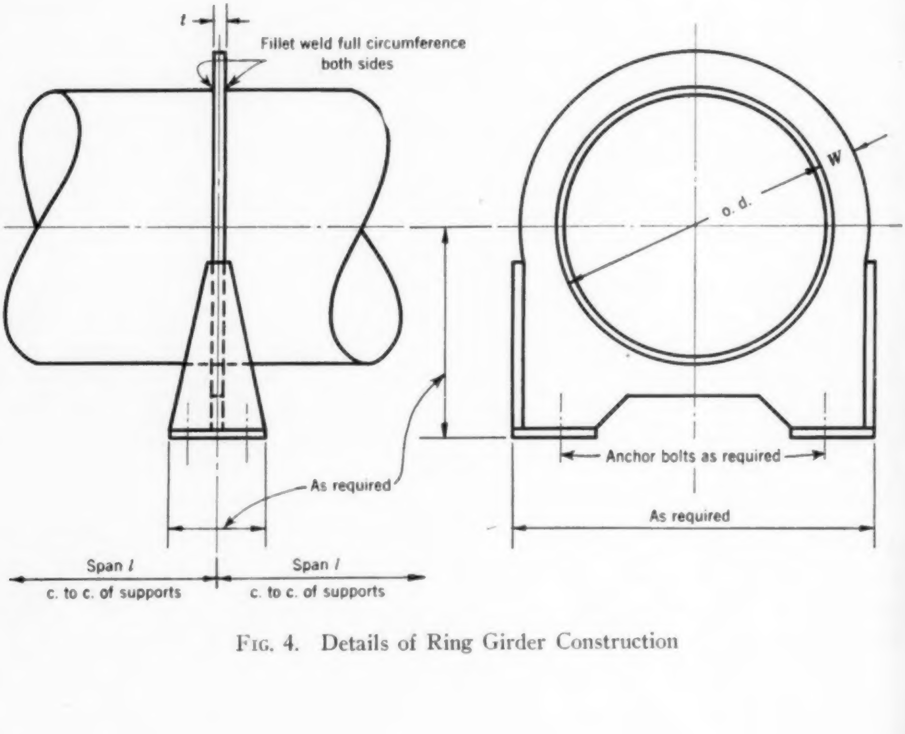

FIG. 4. Details of Ring Girder Construction

ing head in feet and trace vertically until the diagonal line representing the quantity is intersected. Horizontally to the left the horsepower is given. On the same horsepower line, find the intersection with the diagonal line representing the required pumping period. Vertically above this intersection the pumping cost is given. For example: with a cost of 3¢ per kilowatt-hour, determine the cost of pumping 2,000 gpm. against a head of 10 ft. for one year of 300 days at 24 hours per day.

Entering the bottom of the diagram on the vertical line marked 10, trace upward to the intersection with the diagonal line marked 20 (2,000 gpm.). At the left extremity of the horizontal line through this point 6.8 hp. is noted. Vertically above the intersection of this horsepower line with the diagonal line *E*, the chart cost is given as $365 at 1¢ per kilowatt-hour. The cost at 3¢ per kilowatt-hour (3 × 365) is $1,095. As a check on chart accuracy the calculated horsepower is 6.72 and the calculated cost $1,082.80.

TABLE 10

*Standard Sizes, Wall Thickness and Weight of Electric Fusion Welded Steel Pipe in 6- to 36-in. Size Range**

1	2	3	4	5	6	7	8	9	10	11	12
	Wall Thickness—*in.*										
o.d.† *in.*	0.109	0.141	0.172	0.188	0.219	0.250	0.281	0.312	0.375	0.438	0.500
	Weight—*lb./ft.*										
6	6.88	8.80	10.70	11.64	13.51						
6⅝	7.61	9.74	11.85	12.89	14.97						
8	9.22	11.80	14.36	15.64	18.18						
8⅝	9.95	12.74	15.20	16.90	19.64	22.36					
10	11.55	14.81	18.04	19.65	22.85	26.03					
10¾‡	12.43	15.93	19.42	21.15	24.60	28.04	31.20‡				
12	13.89	17.81	21.71	23.65	27.52	31.37	35.20				
12¾	14.77	18.94	23.09	25.16	29.28	33.38	37.45	41.51			
14		20.82	25.38	27.66	32.20	36.71	41.21	45.68			
16		23.82	29.06	31.66	36.87	42.05	47.22	52.36	62.58		
18		26.82	32.73	35.67	41.54	47.39	53.22	59.03	70.59		
20		29.83	36.40	39.67	46.21	52.73	59.23	65.71	78.60	91.41	
22			40.07	43.68	50.88	58.07	65.24	72.38	86.61	100.75	114.81
24			43.74	47.68	55.56	63.41	71.25	79.06	94.62	110.10	125.49
26				51.69	60.23	68.75	77.25	85.73	102.63	119.44	136.17
28				55.69	64.90	74.09	83.26	92.41	110.64	128.79	146.85
30				59.70	69.58	79.43	89.27	99.08	118.65	138.13	157.53
32						84.77	95.28	105.76	126.66	147.48	168.21
34						90.11	101.28	112.43	134.67	156.82	178.89
36						95.45	107.29	119.11	142.68	166.17	189.57

* Under certain conditions, steel pipe may be secured having a nominal inside diameter equal to nominal size.
† Outside diameter. The JOURNAL prefers the lower case form of abbreviation to the use of "O.D.," as in the original manuscript.
‡ Pipe of 10-in. o.d. is furnished in 0.279-in. wall thickness.

Determining Wall Thickness

The wall thickness of steel pipe is influenced by each of the following factors:

1. Internal pressure
2. External pressure
   a. Uniform loading
   b. Trench loading
3. Special physical loading
   a. Lined pipe in transit
   b. Pipe used as bridge
4. Resistance to corrosion
5. Code or regulation requirements

It is necessary to investigate each of these factors separately. The final wall thickness selected will be determined by that factor which gives the greatest value.

TABLE 11

Allowances for Water Hammer

Diam. of Pipe *in.*	Water-hammer *psi.*	Diam. of Pipe *in.*	Water-hammer *psi.*
4–10	120	24	85
12–14	110	30	80
16–18	100	36	75
20	90	42–60	70

Internal Pressure

Except in sizes of steel pipe larger than those considered here (6–36 in. range), it is customary to design for a minimum internal working pressure of 100 psi., including water hammer allowance.

In low-pressure flow lines no allowance is ordinarily made for water hammer. Consequently, the design pressure equals the static pressure. In common pumping lines, the design pressure is usually taken as 150 per cent of the static pressure, thus allowing 50 per cent of the static head for water hammer.

Lines operating under high pressure should be investigated for possible water hammer. Under unfavorable conditions, the surge pressure may amount to several times the static pressure. The allowances for water hammer given in Table 11 are quoted as American recommended practice used in the design of cast-iron pipe.

Allowable working pressures, as well as bursting pressures, are given in Table 12 for steel water pipe conforming with the requirements of the *A.W.W.A. Standard Specifications* 7A.3 (1) and 7A.4 (2). Also given in the table are the allowable working

FIG. 5. Ring Girder Construction

pressures recorded in (or as calculated in accordance with) the Underwriters' Laboratories, Inc., "Report on Steel Pipe Lines for Underground Water Service" (6) and in the Underwriters' Laboratories Standard, Special Investigation 888–38. These latter figures are calculated using methods established in the American Standard Code for Pressure Piping and accepted by Underwriters' Laboratories, Inc.

External Pressure

Uniform loading is imposed by outside atmospheric or hydrostatic pressure acting radially. The approximate collapsing pressure of steel pipe under

TABLE 12

Working Pressure and Approximate Bursting Pressure of Steel Pipe for Water Service

1	2	3	4	5	6
		Working Pressure			
			Underwriters' Laboratories*		
Size of Pipe, o.d. *in.*	Wall Thickness *in.*	A.W.W.A. 7A.4 *psi.*	Supply and Trans. *psi.*	Distr. *psi.*	Bursting Pressure *psi.*
$6\frac{5}{8}$	0.172	650	350	†	2,600
	0.188	710	400	†	2,840
	0.219	830	500	†	3,300
$8\frac{5}{8}$	0.172	490	300	†	2,000
	0.188	550	300	†	2,180
	0.250	730	500	250	2,900
$10\frac{3}{4}$	0.188	440	250	†	1,750
	0.250	580	400	250	2,330
	0.279	650	450	250	2,600
$12\frac{3}{4}$	0.188	370	250	†	1,480
	0.250	490	350	200	1,960
	0.312	610	450	250	2,450
14	0.188	340	200	†	1,340
	0.250	450	300	150	1,780
	0.312	560	400	250	2,230
16	0.188	290	150	†	1,180
	0.250	390	250	150	1,560
	0.312	490	350	200	1,950
18	0.188	260	150	†	1,040
	0.250	350	250	150	1,390
	0.312	430	300	200	1,730
20	0.188	240	150	†	940
	0.250	310	200	100	1,250
	0.312	390	250	150	1,560
24	0.188	200	100	†	780
	0.250	260	150	100	1,040
	0.375	390	300	150	1,560
30	0.250	210‡	150		
	0.375	310‡	250		
	0.500	420‡	300		
36	0.250	170‡	100		
	0.375	260‡	200		
	0.500	350‡	250		

* Pressures higher than 250 psi. shown in this table have been calculated using methods outlined in Appendix III of "Report on Steel Pipe Lines for Underground Water Service" (6).

† Thinner wall than permitted in distribution systems.

‡ These sizes are included in A.W.W.A. 7A.3, but pressures are calculated on same basis as for 7A.4.

TABLE 13

Approximate Collapsing Pressure of Steel Pipe

Nominal Size *in.*	Wall Thickness *in.*	Collapsing Pressure *psi.*
6	0.172	1,180
	0.1875	1,530
	0.250	3,640
8	0.172	500
	0.1875	650
	0.250	1,530
10	0.1875	330
	0.250	780
	0.3125	1,530
12	0.1875	190
	0.250	450
	0.3125	890
14	0.1875	120
	0.250	290
	0.3125	560
16	0.1875	80
	0.250	190
	0.3125	370
18	0.1875	60
	0.250	140
	0.3125	260
20	0.1875	40
	0.250	100
	0.3125	190
24	0.1875	25
	0.250	60
	0.375	190
30	0.250	30
	0.375	100
	0.500	230
36	0.250	17
	0.375	60
	0.500	140

these circumstances is given in Table 13. A safety factor of two applied to the pressures given in Table 13 is recommended as good design practice.

Trench loading is of such character that steel pipe of commonly used thickness placed in a trench of normal width, backfilled with reasonable care and covered to a depth at least equal to the pipe diameter, is virtually uncrushable under the earth load or the usually encountered dead load or live load. The pipe, however, will deflect vertically and increase slightly in horizontal diameter. Published information on this problem is available (4).

Table 14 gives the average expected deflection of steel pipe in trenches. Average bedding and backfilling conditions have been assumed. The truck loading is the same as used by the American Standards Association Committee A21 (7) in making computations of the strength and thickness of cast-iron pipe. It is to be expected that in individual cases some variation from the tabulated figures will occur.

Special Physical Loading

Enamel-lined pipe must be thick enough to prevent damage to the lining while shipping and installing. This minimum thickness depends upon the type of lining, the shipping and installing facilities, length of haul, weather conditions and other factors. It is best to consult with pipe manufacturers and coating contractors on these points, because local conditions may, and probably will, govern the decision. The practice for rail shipment followed by one steel water-pipe manufacturer is given in Table 15.

Pipe acting as a self-supporting bridge may rest upon suitably padded concrete saddles (Fig. 3) or may be supported by means of ring girders or flange rings welded to the pipe (Fig. 4, 5). Pipe cost is lower when saddles are used and there is more flexibility in field erection. Longer spans are possible with ring girder construction.

This paper gives detailed calculations for pipe on saddles. But since

TABLE 14

*Deflection of Steel Pipe Under External Load in Trenches**

1	2	3	4	5	6	7	8
Nominal Size *in.*	2% of Diam. *in.*	Wall Thickness—*in.*		*d* = Deflection—*in.*			
				5-ft. Cover		10-ft. Cover	
		Fraction	Decimal	No Truck	With Truck	No Truck	With Truck
6	0.12	1/8	0.1250	0.01	0.02	0.02	0.02
		3/16	0.1875	0.00	0.01	0.01	0.01
8	0.16	1/8	0.1250	0.03	0.07	0.06	0.07
		3/16	0.1875	0.01	0.02	0.02	0.02
10	0.20	1/8	0.1250	0.07	0.17	0.15	0.18
		3/16	0.1875	0.03	0.06	0.05	0.07
12	0.24	1/8	0.1250	0.15	0.32	0.27	0.33
		3/16	0.1875	0.06	0.12	0.10	0.12
		1/4	0.2500	0.03	0.06	0.05	0.06
14	0.28	1/8	0.1250	0.21	0.48	0.42	0.52
		3/16	0.1875	0.09	0.21	0.19	0.24
		1/4	0.2500	0.04	0.10	0.09	0.11
16	0.32	1/8	0.1250	0.30	0.60	0.56	0.68
		3/16	0.1875	0.15	0.31	0.28	0.35
		1/4	0.2500	0.08	0.16	0.14	0.18
18	0.36	3/16	0.1875	0.21	0.41	0.39	0.47
		1/4	0.2500	0.12	0.22	0.21	0.26
		5/16	0.3125	0.07	0.13	0.13	0.15
20	0.40	3/16	0.1875	0.28	0.53	0.49	0.59
		1/4	0.2500	0.17	0.31	0.29	0.35
		5/16	0.3125	0.10	0.19	0.18	0.21
24	0.48	3/16	0.1875	0.41	0.75	0.71	0.83
		1/4	0.2500	0.29	0.54	0.50	0.59
		3/8	0.3750	0.14	0.24	0.23	0.27
30	0.60	1/4	0.2500	0.40	0.71	0.70	0.83
		5/16	0.3125	0.31	0.54	0.54	0.64
		3/8	0.3750	0.23	0.40	0.40	0.48
36	0.72	1/4	0.2500	0.48	0.83	0.87	1.02
		5/16	0.3125	0.41	0.71	0.75	0.87
		3/8	0.3750	0.34	0.58	0.62	0.72
42	0.84	1/4	0.2500	0.53	0.98	0.95	1.14
		3/8	0.3750	0.44	0.80	0.78	0.92
		1/2	0.5000	0.32	0.57	0.57	0.68
48	0.96	5/16	0.3125	0.52	0.87	0.94	1.09
		3/8	0.3750	0.48	0.81	0.87	1.01
		7/16	0.4375	0.43	0.73	0.78	0.91
		1/2	0.5000	0.38	0.65	0.70	0.81
60	1.20	3/8	0.3750	0.57	0.98	1.05	1.22
		1/2	0.5000	0.51	0.87	0.95	1.10

* Trench width equals pipe o.d. plus 2 ft. Field conditions: flat-bottomed trench, tamped backfill.

the ring girder method more properly applies to pipe larger than 36 in., it is outside the scope of this paper and will not be treated here. Suffice it to say that full beam strength of the pipe may be secured by proper treatment at the supports (8).

In general, the ordinary theory of flexure applies when a circular pipe is supported at intervals, is held circular at and between the supports and is completely filled. If the pipe is only partially filled and the cross section at points between supports becomes out-

of-round, the maximum fiber stress is considerably greater than indicated by the ordinary flexure formula, but the stress is never greater for the partially filled condition than for the filled condition (9).

In the case of a pipe carrying internal pressure, the Poisson ratio effect of the hoop stress, which produces lateral tension, must be added to the flexural stress to obtain the total beam stress.

TABLE 15

*Suggested Minimum Wall Thickness of Spun Coal-Tar Enamel-lined Steel Pipe for Rail Shipment**

Size *in.*	Min. Wall Thickness *in.*	Size *in.*	Min. Wall Thickness *in.*
$6\frac{5}{8}$	0.172	22	0.219
$8\frac{5}{8}$	0.172	24	0.219
$10\frac{3}{4}$	0.188	26	0.219
$12\frac{3}{4}$	0.188	28	0.250
14	0.188	30	0.250
16	0.188	32	0.250
18	0.188	34	0.250
20	0.219	36	0.250

* Reduced wall thicknesses may be used under favorable circumstances.

Excessive deflection should be avoided when pipe acts as a beam. A maximum deflection of 1/360 of the span is suggested as good practice. This is the same as is used for beams carrying plastered ceilings.

Saddle supports cause high local stresses both longitudinally and circumferentially in unstiffened, comparatively thin wall pipe at the tips and edges of the supports. Stresses vary with the load, with the diameter-wall thickness ratio, and with the angle of contact with the pipe. In practice the contact angle varies from 90 to 120 deg. For equal load, the stresses are less for a large contact angle than for a small one, and, contrary to general belief, their intensity is practically independent of the width of the saddle (dimension *B*, Fig. 3). The width of the saddle may therefore be that which is most desirable from the standpoint of good pier design.

Since saddle supports cause critical points of stress in the metal adjacent to the saddle edges, it is frequently more economical to increase the wall thickness of the pipe when it is overstressed than it is to provide stiffening rings. This is especially true where pipe sizes are 36 in. in diameter and smaller. Even a small increase in wall thickness has a great stiffening effect. The whole length of the span may be thickened or, alternatively, only a length at the saddle support—equal to about two pipe diameters plus saddle width—need be thickened.

When pipe lengths are joined by Dresser couplings or flanges, these should be placed as close as possible outside the support in the case of single spans and at points of minimum bending moment in the case of multiple spans.

The pipe should be held in each saddle by a steel hold-down strap bolted to the concrete. Secure anchorages must be provided at intervals in multiple span installations.

The ability of steel pipe to resist saddle load has sometimes been greatly underestimated by designers. Unnecessary expense has thus been entailed, because more supports have been provided than were necessary. According to one authority (9), the maximum value of the *localized* stresses in a pipe

which fits the saddle well probably does not exceed that given by the formula,

$$S_l = k\frac{P}{t^2}\log\left(\frac{R}{t}\right)$$

in which S_l represents the localized stress (psi.), P the total saddle reaction (lb.), R the pipe radius (in.), t the pipe wall thickness (in.) and $k = 0.02 - 0.00012\ [A - 90]$, where A is in degrees (see Fig. 3 for A).

Table 16 gives values of P for various sizes and wall thicknesses of pipe for a 1,000-lb. increment of stress S_l. Column 3 applies when 90-deg. contact saddles are used, and column 4 when the contact angle is 120 deg. Loads are directly proportional for other values of S_l.

To the localized stress S_l must be added certain other stresses to determine the total stress. Let

S_f = flexure stress in span
S_p = ring stress due to internal water pressure
$S_b = S_f + 0.25S_p$ = maximum beam stress in span
S_l = localized stress at saddle
S_t = maximum stress at saddle.

Then, for single or multiple spans *of uniform thickness,*

$$S_t = S_b + S_l$$

It should be noted that S_t is the maximum stress at the *saddle*. Any pipe selected must meet two requirements. The maximum beam stress, S_b, in the span must be within the allowable limit, and the maximum stress at the saddle also must be within the allowable limit. One or the other will govern.

The flexure stress, S_f, should be calculated in the usual manner. In single spans this stress is maximum at the center between supports and may be quite small over the support if flexible joints are used at the pipe ends. In multiple-span types, the flexure stress in rigidly joined pipe will be that indicated by the theory of continuous beams. However, for conservative design it is suggested that all bending stress, both between and at the saddles, be considered to be that existing in the center of a simple span.

Tables 16 and 17 have been prepared to aid in solving problems of self-supporting pipe spans. The solution is found by trial and error. First, assume a wall thickness for which S_f is about 10,000 psi. when the span is somewhat greater than required. Interpolate S_f for span desired. Find S_p from Table 17 and determine S_b. It should not exceed the allowable maximum stress. Determine the reaction load for the span desired using column 5 of Table 16. Then determine S_l using the data in column 3 or 4 of Table 16. Add S_l and S_b. This gives S_t, which should also not exceed the allowable maximum stress. If it does, one of two things may be done. First, a thicker wall may be selected for the whole pipe and the smaller value of S_t recalculated, which should then satisfy the stress requirement. Alternatively, a *thinner* wall may be selected for the main span and a *heavier* wall for a distance of two pipe diameters plus saddle width over the saddle. In the alternative case, the S_b to be used in determining the total *localized* stress S_t is that which would exist had the thicker wall pipe been used for the whole span. Two problems will show the use of the tables.

Problem 1: A 30-in. pipe carrying 150 psi. pressure is to span 65 ft. over a single opening using 120-deg. con-

TABLE 16

Data on Saddle Loads, Pipe Weights and Spans

1	2	3	4	5	6	7	8	9	10	11
o.d. *in.*	Wall Thickness *in.*	Values of *P* for S_t = 1,000 psi.		Weight of Pipe and Water *lb./ft.*	Values of Span *l* for S_f as Shown					
		A = 90°	*A* = 120°		S_f 2,500	S_f 5,000	S_f 7,500	S_f 10,000	S_f 12,500	S_f 15,000
$6\frac{5}{8}$	0.141	725	885	25	18	25	31	36	40	44
	0.188	1,420	1,730	28	20	29	35	41	46	50
	0.250	2,780	3,400	32	22	32	39	45	50	55
$8\frac{5}{8}$	0.141	670	815	38	18	25	31	36	40	44
	0.188	1,300	1,580	42	21	30	36	42	47	51
	0.250	2,470	3,020	47	23	33	40	46	51	56
$10\frac{3}{4}$	0.188	1,210	1,480	59	22	31	38	44	49	54
	0.250	2,350	2,860	66	23	33	41	47	52	58
	0.312	3,940	4,800	70	26	37	45	52	58	64
$12\frac{3}{4}$	0.188	1,150	1,410	80	22	32	39	45	50	55
	0.250	2,220	2,710	88	24	35	42	49	55	60
	0.312	3,710	4,530	97	27	38	47	54	60	66
14	0.188	1,120	1,370	95	22	32	39	45	50	55
	0.250	2,160	2,630	104	24	35	42	49	55	60
	0.312	3,600	4,390	113	27	38	47	54	60	66
16	0.188	1,080	1,320	119	23	33	40	46	51	56
	0.250	2,080	2,530	129	25	35	43	50	56	61
	0.312	3,450	4,210	139	27	39	47	55	61	67
18	0.188	1,050	1,280	147	23	33	41	47	52	58
	0.250	2,010	2,450	158	25	36	44	51	57	62
	0.312	3,330	4,070	170	28	40	48	56	63	68
20	0.188	1,020	1,250	176	24	34	42	48	54	59
	0.250	1,950	2,380	189	26	37	45	52	58	64
	0.312	3,230	3,940	212	29	41	50	58	65	71
24	0.188	980	1,190	244	25	35	43	50	56	61
	0.250	1,860	2,270	259	27	38	47	54	60	66
	0.375	4,670	5,700	291	31	44	54	62	69	76
30	0.250	1,760	2,140	385	28	40	48	56	63	68
	0.375	4,390	5,350	425	32	45	55	64	71	78
	0.500	8,460	10,320	464	35	50	61	71	79	87
36	0.250	1,680	2,050	536	28	40	49	57	64	70
	0.375	4,180	5,100	584	33	47	57	66	74	81
	0.500	8,030	9,800	631	36	52	63	73	81	89

TABLE 17

Ring Stress for Given Pressure

1	2	3	4	5	6	7	8
o.d. *in.*	Wall Thickness *in.*	Ring Stress, S_p, for Internal Pressure (psi.) as Shown					
		$p = 50$	$p = 75$	$p = 100$	$p = 150$	$p = 200$	$p = 250$
$6\frac{5}{8}$	0.141	1,170	1,760	2,350	3,520	4,700	5,870
	0.188	880	1,320	1,760	2,640	3,520	4,410
	0.250	660	990	1,320	1,980	2,640	3,310
$8\frac{5}{8}$	0.141	1,530	2,290	3,060	4,580	6,110	7,640
	0.188	1,150	1,720	2,290	3,440	4,580	5,740
	0.250	860	1,290	1,720	2,580	3,440	4,320
$10\frac{3}{4}$	0.188	1,430	2,140	2,860	4,280	5,710	7,140
	0.250	1,080	1,610	2,150	3,220	4,300	5,380
	0.312	860	1,290	1,720	2,580	3,440	4,300
$12\frac{3}{4}$	0.188	1,690	2,540	3,390	5,080	6,780	8,480
	0.250	1,280	1,910	2,550	3,820	5,100	6,380
	0.312	1,020	1,540	2,045	3,070	4,090	5,120
14	0.188	1,850	2,780	3,720	5,560	7,420	9,280
	0.250	1,400	2,100	2,800	4,200	5,600	7,000
	0.312	1,120	1,680	2,240	3,360	4,480	5,610
16	0.188	2,130	3,180	4,260	6,380	8,520	10,640
	0.250	1,600	2,390	3,200	4,780	6,390	7,980
	0.312	1,280	1,930	2,560	3,860	5,140	6,420
18	0.188	2,390	3,580	4,790	7,160	9,550	11,950
	0.250	1,800	2,690	3,600	5,380	7,180	8,980
	0.312	1,440	2,160	2,880	4,320	5,760	7,200
20	0.188	2,680	3,990	5,320	7,980	10,620	13,290
	0.250	2,000	3,000	4,000	6,000	8,000	10,000
	0.312	1,600	2,400	3,210	4,800	6,400	8,000
24	0.188	3,180	4,760	6,370	9,540	12,720	15,890
	0.250	2,390	3,580	4,790	7,160	9,550	11,950
	0.375	1,600	2,390	3,200	4,780	6,390	7,980
30	0.250	2,990	4,480	5,990	8,960	11,900	14,950
	0.375	2,000	3,000	4,000	6,000	8,000	10,000
	0.500	1,500	2,250	3,000	4,500	6,000	7,500
36	0.250	3,600	5,390	7,190	10,790	14,380	17,980
	0.375	2,390	3,580	4,790	7,160	9,550	11,950
	0.500	1,800	2,690	3,600	5,380	7,180	8,980

TABLE 18

Values of Section Modulus, Radius of Gyration and Area of Steel in Cross Section for Steel Pipe

1 Size of Pipe o.d. *in.*	2 Wall Thickness *in.*	3 Section Modulus *in.*^{3}	4 Radius of Gyration *in.*	5 Area of Steel *sq.in.*
6$\frac{5}{8}$	0.172	5.47	2.282	3.487
	0.188	5.93	2.277	3.802
	0.219	6.83	2.266	4.407
8$\frac{5}{8}$	0.172	9.46	2.989	4.568
	0.188	10.26	2.984	4.983
	0.250	13.39	2.962	6.578
10$\frac{3}{4}$	0.188	16.15	3.735	6.238
	0.250	21.16	3.713	8.247
	0.279	23.60	3.703	9.242
12$\frac{3}{4}$	0.188	22.91	4.442	7.419
	0.250	30.09	4.420	9.818
	0.312	37.06	4.399	12.191
14	0.188	27.72	4.884	8.158
	0.250	36.48	4.862	10.799
	0.312	44.98	4.841	13.417
16	0.188	36.39	5.591	9.339
	0.250	47.96	5.569	12.370
	0.312	59.24	5.548	15.377
18	0.188	46.24	6.298	10.520
	0.250	61.01	6.276	13.941
	0.312	75.47	6.255	17.337
20	0.188	57.27	7.005	11.701
	0.250	75.65	6.983	15.512
	0.312	93.67	6.962	19.298
24	0.188	82.86	8.419	14.064
	0.250	109.62	8.397	18.653
	0.375	161.87	8.354	27.833
30	0.250	172.37	10.518	23.366
	0.375	255.33	10.475	34.901
	0.500	336.20	10.431	46.339
36	0.250	249.21	12.640	28.078
	0.375	369.93	12.596	41.970
	0.500	488.11	12.552	55.763

tact saddles. Determine its thickness in the span and at the saddle supports so that neither S_b nor S_t exceeds 16,000 psi.

Solution: From column 9 of Table 16, l is 64 ft. for $t = 0.375$ and $S_f = 10{,}000$; and from column 10, l is 71 ft. for $S_f = 12{,}500$. For practical pur-

poses, S_f for $l = 65$ ft. may be determined by interpolation. On this basis $S_f = 10{,}360$.

From Table 17, S_p for 150 psi. is 6,000. Then $0.25S_p = 1{,}500$, and $S_b = 10{,}360 + 1{,}500 = 11{,}860$, which is less than 16,000.

From column 5 of Table 16, the weight of the pipe and contained water is 425 lb. per linear foot. (Any additional live or dead load must be added.) The total reaction at one saddle is $32.5 \times 425 = 13{,}800$ lb. (*Note:* If the design requires the saddle to carry a portion of the approach span weight, this should be added.) From column 4 of Table 16, it is seen that 5,350 lb. of reaction is resisted by each 1,000 psi. of stress S_l. Therefore

$$S_l = \frac{13{,}800}{5{,}350} \times 1{,}000 = 2{,}580.$$

Then $S_t = 11{,}860 + 2{,}580 = 14{,}440$ psi., and, since this is less than the 16,000 psi. maximum fixed, the 30-in., $\frac{3}{8}$-in. thick wall pipe meets the requirements.

The calculated deflection is $1\frac{1}{2}$ in. which is considerably less than 1/360 of the span—$2\frac{3}{16}$ in.

Problem 2: Can 30-in. pipe with a $\frac{1}{4}$-in. wall be used for the central portion of the above span if thickened at the saddle?

Solution: From column 10 of Table 16, l is 63 ft. for $S_f = 12{,}500$ and 68 ft. for $S_f = 15{,}000$. By interpolation, $S_f = 13{,}500$ for $l = 65$ ft. From column 6 of Table 17, $S_p = 8{,}960$. Then $0.25S_p = 2{,}240$ and $S_b = 13{,}500 + 2{,}240 = 15{,}740$. Since this is less than the 16,000 maximum specified, the $\frac{1}{4}$-in. wall pipe may be used in the span,

TABLE 19

Soils Grouped in Order of Corrosive Action on Steel

Group I—Lightly Corrosive

Aeration good. Characterized by no mottling anywhere in soil profile and by very low water table. Includes:
1. Coarse sands or sandy loams
2. Light, textured silt loams
3. Porous loams or clay loams thoroughly oxidized to great depths.

Group II—Average Corrosive

Aeration fair. Characterized by slight mottling in lower part of profile and by low water table. Soils would be considered well drained in an agricultural sense, since no artificial drainage is necessary for crop raising. Includes:
1. Sandy loams
2. Silt loams.

Group III—Badly Corrosive

Aeration poor. Characterized by heavy texture and mottling close to surface with water table at about pipe depth. Soils usually occupy flat areas and would require artificial drainage for crop raising. Includes:
1. Clay loams
2. Clays.

Group IV—Unusually Corrosive

Aeration very poor. Characterized by water table at surface, or by extreme impermeability because of colloidal material contained. Includes:
1. Muck
2. Peat
3. Tidal marsh
4. Adobe clay.

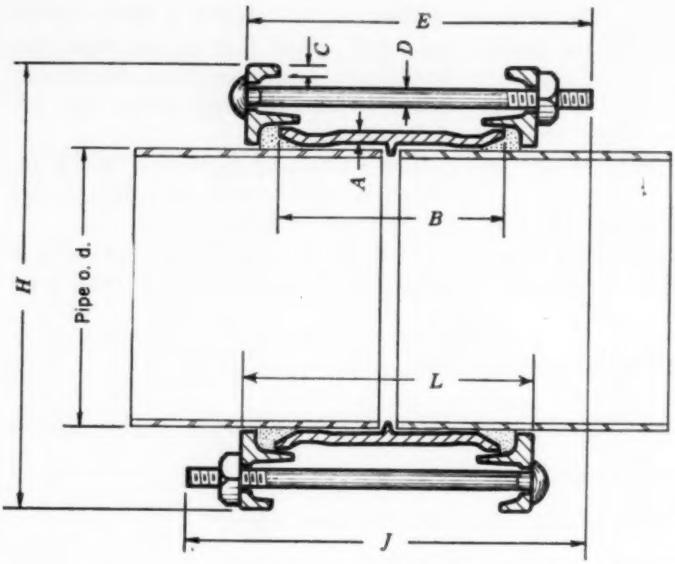

FIG. 6. Style 38 Dresser Coupling
(See Table 21 for Dimensions)

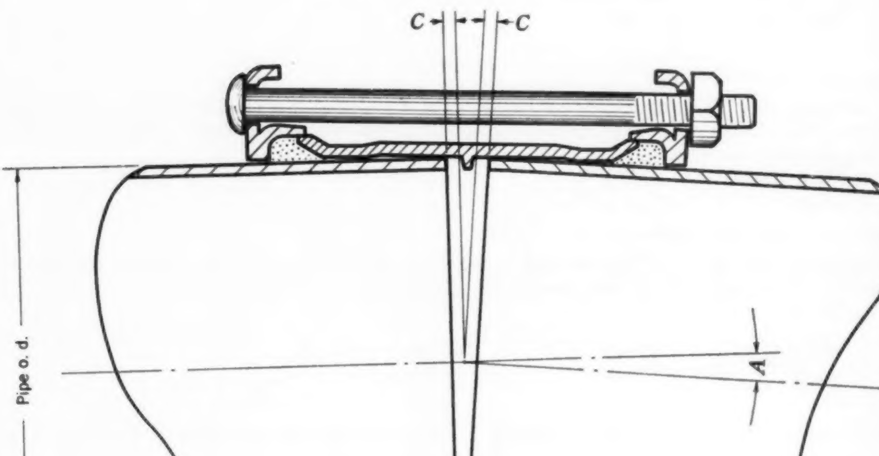

FIG. 7. Dresser Coupling Laying Length

but it is obvious that it must be thickened over the saddle.

Assume 3/8-in. thick pipe over the saddle. The saddle reaction from column 5 of Table 16 is $32.5 \times 385 = 12{,}500$, and the corresponding stress $S_t = \frac{12{,}500}{5{,}350} \times 1{,}000 = 2{,}340$. For practical purposes, the effective S_b which is

TABLE 20

Wall Thickness of Steel Pipe Designed to Function in Soil Groups Shown in Table 19

Size *in.*	1 Uncoated*	2 Uncoated	2 Coated†	3 Coated‡	4 Coated‡
	Wall Thickness—*in.*				
6	0.172	0.281	0.219	0.375	0.438
8	0.172	0.281	0.219	0.375	0.438
10	0.172	0.281	0.219	0.375	0.500
12	0.172	0.312	0.250	0.375	0.500
14	0.188	0.312	0.250	0.375	0.500
16	0.188	0.312	0.250	0.438	0.500
18	0.188	0.312	0.250	0.438	0.500
20	0.188	0.312	0.250	0.438	0.500
22	0.188	0.375	0.281	0.438	0.500
24	0.188	0.375	0.281	0.438	0.500
30	0.219	0.375	0.281	0.438	0.500
36	0.219	0.375	0.281	0.438	0.500

* Wall thickness may be reduced if pipe is coal-tar painted or hot-asphalt dipped.

† Coating materials: A.W.W.A. Specification 7A.5 (10) or 7A.6 (11). Exterior coating construction: Coal-tar primer, coal-tar enamel, bonded asbestos felt, white wash (or kraft paper).

‡ Coating materials: A.W.W.A. Specification 7A.5 (10) or 7A.6 (11). Exterior coating construction: Coal-tar primer, coal-tar enamel, bonded asbestos felt, coal-tar enamel, bonded asbestos felt, white wash (or kraft paper).

to be added may be conservatively considered the same as if the 3/8-in. pipe continued across the span. From problem 1, $S_b = 11{,}860$. Therefore, $S_t = 11{,}860 + 2{,}340 = 14{,}200$, and by using 3/8-in. thick pipe over the support, the balance may be 1/4-in. thick.

The maximum saddle stress exists only a few inches from the edge of the saddle, but, to be conservative, it is suggested that the heavier pipe extend one pipe diameter on each side of the support.

The calculated deflection is 2 in., which is less than the 2 3/16-in. suggested maximum.

Table 18 gives values of the section modulus of steel pipe for use when calculating beam strength and also values of the radius of gyration and area of steel for column strength calculations.

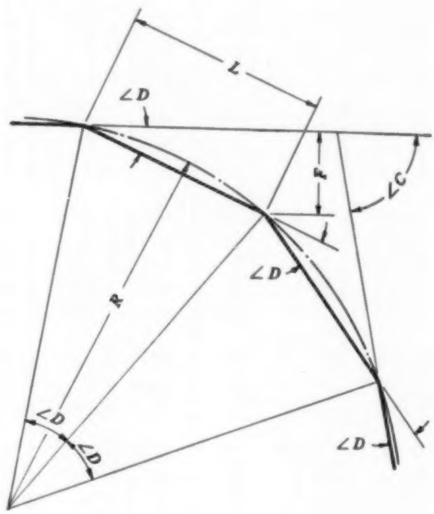

FIG. 8. Layout of Curves

Resistance to Corrosion

Pipe having no protective coating may corrode on the inside due to water action or on the outside due to soil action. Such action results in tuberculation on the inside and pitting on the outside. Experience has shown that neither tuberculation nor outside pitting seriously impairs the *strength* of the pipe.

Internal corrosion should be avoided more because of the reduction in flow

TABLE 21

*Data and Dimensions of Style 38 Dresser Couplings for Steel Pipe**
(See Fig. 6)

1	2	3	4	5	6	7	8	9	10
Steel Pipe o.d.	Middle Ring† Thickness and Length $(A \times B)$	Follower Ring Thickness (C)	Bolt No., Diam. and Length $(D \times E)$	Gasket Section Thickness and Length $(F \times G)$	Over-all Dimensions			Max. Working Press. *psi.*	Approx. Shipping Weight (ea.) *lb.*
					Diam. (H)	Length (J)‡	Length (L)§		
6.000	$\frac{3}{16} \times 4$	0.134	$4-\frac{1}{2} \times 6$	$\frac{3}{8} \times \frac{7}{8}$	9	$7\frac{5}{8}$	$5\frac{1}{4}$	865	11
6.000	$\frac{1}{4} \times 5$	$\frac{1}{4}$	$6-\frac{5}{8} \times 8$	$\frac{1}{2} \times 1$	$9\frac{7}{8}$	$10\frac{1}{8}$	$6\frac{7}{8}$	1,130	24
6.000	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$6-\frac{5}{8} \times 10$	$\frac{1}{2} \times 1$	$9\frac{7}{8}$	$12\frac{1}{8}$	$8\frac{7}{8}$	1,130	28
6.625	$\frac{3}{16} \times 4$	0.134	$4-\frac{1}{2} \times 6$	$\frac{3}{8} \times \frac{7}{8}$	$9\frac{5}{8}$	$7\frac{5}{8}$	$5\frac{1}{4}$	787	12
6.625	$\frac{1}{4} \times 5$	$\frac{1}{4}$	$6-\frac{5}{8} \times 8$	$\frac{1}{2} \times 1$	$10\frac{1}{2}$	$10\frac{1}{8}$	$6\frac{7}{8}$	1,035	25
6.625	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$6-\frac{5}{8} \times 10$	$\frac{1}{2} \times 1$	$10\frac{1}{2}$	$12\frac{1}{8}$	$8\frac{7}{8}$	1,035	29
8.000	$\frac{3}{16} \times 4$	0.134	$5-\frac{1}{2} \times 6$	$\frac{3}{8} \times \frac{7}{8}$	11	$7\frac{5}{8}$	$5\frac{1}{4}$	661	14
8.000	$\frac{1}{4} \times 5$	$\frac{1}{4}$	$6-\frac{5}{8} \times 8$	$\frac{1}{2} \times 1$	$11\frac{7}{8}$	$10\frac{1}{8}$	$6\frac{7}{8}$	870	30
8.000	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$6-\frac{5}{8} \times 10$	$\frac{1}{2} \times 1$	$11\frac{7}{8}$	$12\frac{1}{8}$	$8\frac{7}{8}$	870	35
8.625	$\frac{3}{16} \times 4$	0.134	$6-\frac{1}{2} \times 6$	$\frac{3}{8} \times \frac{7}{8}$	$11\frac{5}{8}$	$7\frac{5}{8}$	$5\frac{1}{4}$	617	15
8.625	$\frac{1}{4} \times 5$	$\frac{1}{4}$	$6-\frac{5}{8} \times 8$	$\frac{1}{2} \times 1$	$12\frac{7}{16}$	$10\frac{1}{8}$	$6\frac{7}{8}$	811	31
8.625	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$6-\frac{5}{8} \times 10$	$\frac{1}{2} \times 1$	$12\frac{7}{16}$	$12\frac{1}{8}$	$8\frac{7}{8}$	811	36
8.625	$\frac{5}{16} \times 5$	$\frac{5}{16}$	$6-\frac{5}{8} \times 8\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	$12\frac{9}{16}$	$10\frac{7}{8}$	$7\frac{3}{8}$	1,000	36
8.625	$\frac{5}{16} \times 7$	$\frac{5}{16}$	$6-\frac{5}{8} \times 10\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	$12\frac{9}{16}$	$12\frac{7}{8}$	$9\frac{3}{8}$	1,000	42
10.000	$\frac{1}{4} \times 5$	$\frac{3}{16}$	$8-\frac{5}{8} \times 7\frac{1}{2}$	$\frac{1}{2} \times 1$	$13\frac{7}{8}$	$9\frac{5}{8}$	$6\frac{3}{8}$	705	30
10.000	$\frac{1}{4} \times 5$	$\frac{1}{4}$	$8-\frac{5}{8} \times 8$	$\frac{1}{2} \times 1$	$13\frac{7}{8}$	$10\frac{1}{8}$	$6\frac{7}{8}$	705	38
10.000	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$8-\frac{5}{8} \times 10$	$\frac{1}{2} \times 1$	$13\frac{7}{8}$	$12\frac{1}{8}$	$8\frac{7}{8}$	705	44
10.750	$\frac{1}{4} \times 5$	$\frac{1}{4}$	$8-\frac{5}{8} \times 8$	$\frac{1}{2} \times 1$	$14\frac{5}{8}$	$10\frac{1}{8}$	$6\frac{7}{8}$	660	41
10.750	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$8-\frac{5}{8} \times 10$	$\frac{1}{2} \times 1$	$14\frac{5}{8}$	$12\frac{1}{8}$	$8\frac{7}{8}$	660	47
10.750	$\frac{5}{16} \times 5$	$\frac{5}{16}$	$8-\frac{5}{8} \times 8\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	$14\frac{3}{4}$	$10\frac{7}{8}$	$7\frac{3}{8}$	815	48
10.750	$\frac{5}{16} \times 7$	$\frac{5}{16}$	$8-\frac{5}{8} \times 10\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	$14\frac{3}{4}$	$12\frac{7}{8}$	$9\frac{3}{8}$	815	57
12.000	$\frac{1}{4} \times 5$	$\frac{3}{16}$	$8-\frac{5}{8} \times 7\frac{1}{2}$	$\frac{1}{2} \times 1$	$15\frac{7}{8}$	$9\frac{5}{8}$	$6\frac{3}{8}$	593	35
12.000	$\frac{1}{4} \times 5$	$\frac{1}{4}$	$8-\frac{5}{8} \times 8$	$\frac{1}{2} \times 1$	$16\frac{1}{8}$	$10\frac{1}{8}$	$6\frac{7}{8}$	593	44
12.000	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$8-\frac{5}{8} \times 10$	$\frac{1}{2} \times 1$	$16\frac{1}{8}$	$12\frac{1}{8}$	$8\frac{7}{8}$	593	51
12.750	$\frac{1}{4} \times 5$	$\frac{1}{4}$	$8-\frac{5}{8} \times 8$	$\frac{1}{2} \times 1$	$16\frac{3}{4}$	$10\frac{1}{8}$	$6\frac{7}{8}$	561	47
12.750	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$8-\frac{5}{8} \times 10$	$\frac{1}{2} \times 1$	$16\frac{3}{4}$	$12\frac{1}{8}$	$8\frac{7}{8}$	561	54
12.750	$\frac{5}{16} \times 5$	$\frac{5}{16}$	$8-\frac{5}{8} \times 8\frac{1}{2}$	$\frac{1}{2} \times 0\frac{1}{8}$	$16\frac{7}{8}$	$10\frac{7}{8}$	$7\frac{3}{8}$	694	57
12.750	$\frac{5}{16} \times 7$	$\frac{5}{16}$	$8-\frac{5}{8} \times 10\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	$16\frac{7}{8}$	$12\frac{7}{8}$	$9\frac{3}{8}$	694	65
14.000	$\frac{1}{4} \times 5$	$\frac{1}{4}$	$8-\frac{5}{8} \times 8\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	18	$11\frac{1}{8}$	$7\frac{1}{8}$	513	51
14.000	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$8-\frac{5}{8} \times 10\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	18	$13\frac{1}{8}$	$9\frac{1}{8}$	513	60
14.000	$\frac{5}{16} \times 5$	$\frac{5}{16}$	$8-\frac{5}{8} \times 8\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	$18\frac{1}{8}$	$10\frac{7}{8}$	$7\frac{3}{8}$	635	62
14.000	$\frac{5}{16} \times 7$	$\frac{5}{16}$	$8-\frac{5}{8} \times 10\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	$18\frac{1}{8}$	$12\frac{7}{8}$	$9\frac{3}{8}$	635	71
16.000	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$10-\frac{5}{8} \times 10\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	20	$13\frac{1}{8}$	$9\frac{1}{8}$	451	70
16.000	$\frac{5}{16} \times 7$	$\frac{5}{16}$	$10-\frac{5}{8} \times 10\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	$20\frac{1}{8}$	$12\frac{7}{8}$	$9\frac{3}{8}$	559	80
16.000	$\frac{3}{8} \times 7$	$\frac{11}{32}$	$10-\frac{5}{8} \times 10\frac{1}{2}$	$\frac{5}{8} \times 1\frac{3}{16}$	$20\frac{7}{16}$	$12\frac{3}{4}$	$9\frac{5}{8}$	666	98

TABLE 21—*Continued*

1	2	3	4	5	6	7	8	9	10
Steel Pipe o.d.	Middle Ring† Thickness and Length ($A \times B$)	Follower Ring Thickness (C)	Bolt No., Diam. and Length ($D \times E$)	Gasket Section Thickness and Length ($F \times G$)	Over-all Dimensions			Max. Working Press. *psi.*	Approx. Shipping Weight (ea.) *lb.*
					Diam. (H)	Length (J)‡	Length (L)§		
18.000	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$10—\frac{5}{8} \times 10\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	22	$13\frac{1}{8}$	$9\frac{1}{8}$	402	75
18.000	$\frac{5}{16} \times 7$	$\frac{5}{16}$	$10—\frac{5}{8} \times 10\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	$22\frac{1}{8}$	$12\frac{7}{8}$	$9\frac{3}{8}$	500	91
18.000	$\frac{3}{8} \times 7$	$\frac{11}{32}$	$10—\frac{5}{8} \times 10\frac{1}{2}$	$\frac{5}{8} \times 1\frac{3}{16}$	$22\frac{7}{16}$	$12\frac{3}{4}$	$9\frac{5}{8}$	595	111
20.000	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$12—\frac{5}{8} \times 10\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	$24\frac{1}{16}$	$13\frac{1}{8}$	$9\frac{1}{8}$	363	86
20.000	$\frac{5}{16} \times 7$	$\frac{5}{16}$	$12—\frac{5}{8} \times 10\frac{1}{2}$	$\frac{1}{2} \times 1\frac{1}{8}$	$24\frac{3}{16}$	$12\frac{7}{8}$	$9\frac{3}{8}$	452	104
20.000	$\frac{3}{8} \times 7$	$\frac{11}{32}$	$12—\frac{5}{8} \times 10\frac{1}{2}$	$\frac{5}{8} \times 1\frac{3}{16}$	$24\frac{9}{16}$	$12\frac{3}{4}$	$9\frac{5}{8}$	538	122
22.000	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$14—\frac{5}{8} \times 10$	$\frac{1}{2} \times 1\frac{3}{16}$	26	$12\frac{3}{8}$	$9\frac{1}{8}$	331	98
22.000	$\frac{5}{16} \times 7$	$\frac{5}{16}$	$14—\frac{5}{8} \times 10\frac{1}{2}$	$\frac{5}{8} \times 1\frac{3}{16}$	$26\frac{5}{8}$	$12\frac{7}{8}$	$9\frac{3}{8}$	412	121
22.000	$\frac{3}{8} \times 7$	$\frac{11}{32}$	$14—\frac{5}{8} \times 10\frac{1}{2}$	$\frac{5}{8} \times 1\frac{3}{16}$	$26\frac{3}{4}$	$12\frac{3}{4}$	$9\frac{5}{8}$	491	138
24.000	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$14—\frac{5}{8} \times 10$	$\frac{1}{2} \times 1\frac{3}{16}$	28	$12\frac{3}{8}$	$9\frac{1}{8}$	304	105
24.000	$\frac{5}{16} \times 7$	$\frac{5}{16}$	$14—\frac{5}{8} \times 10\frac{1}{2}$	$\frac{5}{8} \times 1\frac{3}{16}$	29	$12\frac{7}{8}$	$9\frac{3}{8}$	378	137
24.000	$\frac{3}{8} \times 7$	$\frac{11}{32}$	$14—\frac{5}{8} \times 10\frac{1}{2}$	$\frac{5}{8} \times 1\frac{3}{16}$	$29\frac{1}{16}$	$12\frac{3}{4}$	$9\frac{5}{8}$	452	156
30.500	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$18—\frac{5}{8} \times 10$	$\frac{1}{2} \times 1\frac{1}{4}$	$34\frac{1}{2}$	$12\frac{3}{8}$	$9\frac{1}{4}$	248	135
30.625	$\frac{5}{16} \times 7$	$\frac{3}{8}$	$18—\frac{5}{8} \times 10\frac{1}{2}$	$\frac{5}{8} \times 1\frac{1}{4}$	$35\frac{5}{8}$	$12\frac{7}{8}$	$9\frac{3}{8}$	300	182
30.750	$\frac{3}{8} \times 7$	$\frac{3}{8}$	$18—\frac{5}{8} \times 10\frac{1}{2}$	$\frac{5}{8} \times 1\frac{1}{4}$	$35\frac{3}{4}$	$12\frac{7}{8}$	$9\frac{3}{8}$	352	193
31.000	$\frac{1}{2} \times 8$	$\frac{3}{8}$	$18—\frac{5}{8} \times 11\frac{1}{2}$	$\frac{5}{8} \times 1\frac{3}{8}$	36	$13\frac{7}{8}$	$10\frac{1}{2}$	468	231
31.000	$\frac{1}{2} \times 10$	$\frac{3}{8}$	$18—\frac{5}{8} \times 13\frac{1}{2}$	$\frac{5}{8} \times 1\frac{3}{8}$	36	$15\frac{7}{8}$	$12\frac{1}{2}$	468	261
36.500	$\frac{1}{4} \times 7$	$\frac{1}{4}$	$20—\frac{5}{8} \times 10$	$\frac{1}{2} \times 1\frac{3}{8}$	$40\frac{1}{2}$	$12\frac{3}{8}$	$9\frac{1}{2}$	202	160
36.625	$\frac{5}{16} \times 7$	$\frac{3}{8}$	$20—\frac{5}{8} \times 10\frac{1}{2}$	$\frac{5}{8} \times 1\frac{3}{8}$	$41\frac{5}{8}$	$12\frac{7}{8}$	$9\frac{5}{8}$	250	213
36.750	$\frac{3}{8} \times 7$	$\frac{3}{8}$	$20—\frac{5}{8} \times 10\frac{1}{2}$	$\frac{5}{8} \times 1\frac{3}{8}$	$41\frac{3}{4}$	$12\frac{7}{8}$	$9\frac{5}{8}$	298	228
37.000	$\frac{1}{2} \times 8$	$\frac{3}{8}$	$20—\frac{5}{8} \times 11\frac{1}{2}$	$\frac{5}{8} \times 1\frac{3}{8}$	42	$13\frac{7}{8}$	$10\frac{1}{2}$	395	273
37.000	$\frac{1}{2} \times 10$	$\frac{3}{8}$	$20—\frac{5}{8} \times 13\frac{1}{2}$	$\frac{5}{8} \times 1\frac{3}{8}$	42	$15\frac{7}{8}$	$12\frac{1}{2}$	395	309

* Approximate dimensions in inches as shown in Fig. 6.
† Middle rings thicker or longer than those listed can be supplied.
‡ Dimension J (maximum) will be equal to dimension E plus $\frac{1}{2}$ in. (approximate bolt-head thickness) if all bolts are inserted from one side of coupling.
§ Dimension L (over-all length exclusive of bolts) is taken with bolts drawn up finger tight.

capacity than for any other reason. It is prevented by applying coal-tar enamel to the interior surface of the pipe in accordance with the A.W.W.A. specifications (10, 11).

Exterior corrosion of unprotected pipe by soil action is usually more important than interior corrosion. Much information has been gained regarding the rate and extent of soil corrosion of ferrous metals. A consolidation and interpretation of much of this data from the designer's point of view has been published (12).

For convenience, soils may be grouped in an ascending scale of potential corrosivity related to drainage or aeration, as given in Table 19.

The wall thickness and coating of pipe designed to function in the four soil groups in Table 19 are given in Table 20.

Code or Regulation Requirements

Occasionally the minimum wall thickness as determined by technical requirements is less than the minimum fixed by code or regulation, and in such cases the code or regulation requirements will actually govern the final selection.

Field Joints

Various types of field joints may be used with steel water pipe. The two most common types are (1) the mechanical compression sleeve joint of the Dresser coupling type and (2) field welding. Other types are flanges, Victaulic couplings and bell-and-spigot joints.

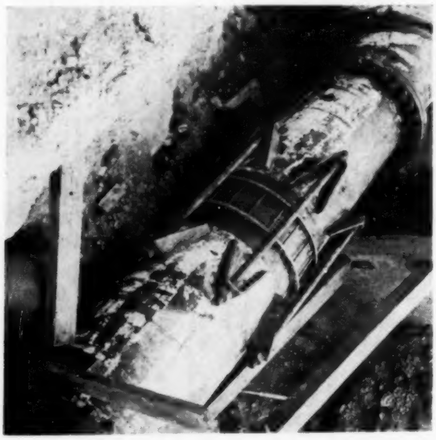

FIG. 9. Joint Harness for Dresser Coupling

Dresser Couplings

Dresser couplings are used on most lines 24 in. and smaller, especially those having coal-tar enamel lining. Very complete technical data have been published (13). A longitudinal section through a standard-pattern style 38 Dresser coupling is given in Fig. 6. Corresponding dimensions are given in Table 21.

Pipe Layout When Using Dresser Couplings

The center stop in Dresser couplings centers the coupling at the joint and prevents the adjacent pipe ends from butting end to end. This increases the laying length of pipe sections. Dimensions of stops in Dresser middle rings are given in Table 22 for rings of different thickness and length. In accurate layouts for straight alignment, the amount of separation should be figured at ¼ in. (0.02 ft.).

TABLE 22

Dimensions of Stops in Dresser Middle Rings

Middle Ring Thickness × Length *in.*	Dimensions of Stop		
	Height *in.*	Width at Top *in.*	Width at Bottom *in.*
$\frac{3}{16} \times 4$	$\frac{5}{32}$	$\frac{1}{16}$	$\frac{1}{8}$
$\frac{1}{4} \times 5$	$\frac{7}{32}$	$\frac{3}{32}$	$\frac{5}{32}$
$\frac{1}{4} \times 7$	$\frac{7}{32}$	$\frac{3}{32}$	$\frac{5}{32}$
$\frac{5}{16} \times 5$	$\frac{7}{32}$	$\frac{3}{32}$	$\frac{5}{32}$
$\frac{5}{16} \times 7$	$\frac{7}{32}$	$\frac{3}{32}$	$\frac{5}{32}$
$\frac{5}{16} \times 7$	$\frac{9}{32}$	$\frac{1}{8}$	$\frac{3}{16}$
$\frac{3}{8} \times 7$	$\frac{9}{32}$	$\frac{1}{8}$	$\frac{3}{16}$
$\frac{1}{2} \times 8$	$\frac{9}{32}$	$\frac{1}{8}$	$\frac{3}{16}$
$\frac{1}{2} \times 10$	$\frac{9}{32}$	$\frac{1}{8}$	$\frac{3}{16}$
$\frac{3}{8} \times 10$	$\frac{5}{16}$	$\frac{1}{8}$	$\frac{3}{16}$

When laying Dresser-coupled pipe on curves, the amount of separation measured on the pipe centerline should be determined using the data in Table 23, as interpreted by Fig. 7.

The accuracy indicated by Tables 22 and 23 is necessary only on plant layout work and other very special jobs. However, when these cases occur, the tabulated data aid layout men and checkers to reach agreement on dimensions.

Data for Pipe Layouts

The profile and alignment of pipelines is frequently staked on a railroad curve basis. It is well to know what pipe lengths are needed to negotiate such curves and to know the offset necessary to locate properly the free end of the pipe section being laid. Table 24 gives the radius of curve possible when using given pipe lengths. Table 25 shows the offset or deflection of the pipe end measured from the projected centerline of the previously laid pipe. Figure 8 visualizes the dimensions to which Tables 24 and 25 refer.

Unless otherwise designated, the length of a survey line is taken as a horizontal distance and not a surface

TABLE 23

*Data for Determining Laying Length of Dresser Couplings for Various Degrees of Deflection and Pipe Diameters**

(See Fig. 7)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		Values of *A*											
Pipe o.d. *in.*	*B in.*	0°30′	1°00′	1°30′	2°00′	2°30′	3°00′	3°30′	4°00′	4°30′	5°00′	5°30′	6°00′
		C—ft.											
4	¼	0.010	0.010	0.013	0.013	0.014	0.015	0.016	0.016	0.017	0.018	0.018	0.019
6	¼	0.010	0.010	0.015	0.015	0.015	0.015	0.020	0.020	0.020	0.021	0.022	0.024
6⅝	¼	0.010	0.010	0.015	0.015	0.015	0.015	0.020	0.020	0.021	0.023	0.024	0.025
8	¼	0.010	0.015	0.015	0.015	0.015	0.020	0.020	0.020	0.023	0.025	0.026	0.028
8⅝	¼	0.010	0.015	0.015	0.015	0.020	0.020	0.020	0.025	0.025	0.026	0.028	0.029
10	¼	0.010	0.015	0.015	0.015	0.020	0.020	0.025	0.025	0.027	0.029	0.030	0.032
10¾	¼	0.010	0.015	0.015	0.020	0.020	0.020	0.025	0.025	0.028	0.030	0.032	0.034
12	¼	0.010	0.015	0.015	0.020	0.020	0.025	0.025	0.025	0.030	0.032	0.034	0.037
12¾	¼	0.010	0.015	0.015	0.020	0.020	0.025	0.025	0.030	0.031	0.034	0.036	0.038
14	¼	0.015	0.015	0.020	0.020	0.025	0.025	0.030	0.030	0.033	0.036	0.038	0.041
16	¼	0.015	0.015	0.020	0.020	0.025	0.025	0.030	0.035	0.037	0.040	0.042	0.045
18	¼	0.015	0.015	0.020	0.025	0.025	0.030	0.035	0.035	0.040	0.043	0.046	0.050
20	¼	0.015	0.015	0.020	0.025	0.030	0.030	0.035	0.040	0.043	0.047	0.050	0.054
22	¼	0.015	0.020	0.020	0.025	0.030	0.035	0.040	0.040	0.046	0.050	0.054	0.058
24	¼	0.015	0.020	0.025	0.025	0.030	0.035	0.040	0.045	0.050	0.054	0.058	0.063
26	¼	0.015	0.020	0.025	0.030	0.035	0.040						
28	¼	0.015	0.020	0.025	0.030	0.035	0.040						
30	¼	0.015	0.020	0.025	0.030	0.035	0.040						
32	¼	0.015	0.020	0.025	0.035	0.040	0.045						
34	¼	0.015	0.020	0.030	0.035	0.040	0.045						
36	¼	0.015	0.025	0.030	0.035	0.045	0.050						

* Laying length of pipe section equals pipe length plus 2*C*.

TABLE 24

*Radius of Curve When Using Dresser Couplings With Various Deflections and Pipe Sections of Different Lengths**
(See Fig. 8)

1	2	3	4	5	6	7	8
Deflection† *D*	Length of Pipe Section—*ft.*‡						
	L = 1	*L* = 5	*L* = 10	*L* = 20	*L* = 30	*L* = 40	*L* = 50
	Radius of Curve (*R*)—*ft.*§						
0°15′	228.833	1144.2	2288.0	4577.0	6865.0	9153.0	11442.0
30′	114.679	573.4	1146.8	2293.6	3440.0	4587.0	5734.0
45′	76.394	381.9	764.0	1528.0	2292.0	3056.0	3820.0
1°00′	57.274	286.4	573.0	1145.0	1718.0	2291.0	2864.0
15′	45.851	229.3	459.0	917.0	1376.0	1834.0	2293.0
30′	38.197	191.0	382.0	764.0	1146.0	1528.0	1910.0
45′	32.733	163.7	327.0	655.0	982.0	1309.0	1637.0
2°00′	28.653	143.3	287.0	573.0	860.0	1146.0	1433.0
15′	25.465	127.3	255.0	509.0	764.0	1019.0	1273.0
30′	22.925	114.6	229.0	459.0	688.0	917.0	1146.0
45′	20.838	104.2	208.0	417.0	625.0	834.0	1042.0
3°00′	19.099	95.5	191.0	382.0	573.0	764.0	955.0
15′	17.634	88.2	176.0	353.0	529.0	705.0	882.0
30′	16.372	81.9	164.0	327.0	491.0	655.0	819.0
45′	15.284	76.4	153.0	306.0	459.0	611.0	764.0
4°00′	14.327	71.6	143.0	287.0	430.0	573.0	716.0
15′	13.484	67.4	135.0	270.0	405.0	539.0	674.0
30′	12.736	63.7	127.0	255.0	382.0	509.0	637.0
45′	12.066	60.3	121.0	241.0	362.0	483.0	603.0
5°00′	11.463	57.3	115.0	229.0	344.0	459.0	573.0
15′	10.918	54.6	109.0	218.0	328.0	437.0	546.0
30′	10.421	52.1	104.0	208.0	313.0	417.0	521.0
45′	9.969	49.8	100.0	199.0	299.0	399.0	498.0
6°00′	9.553	47.8	96.0	191.0	287.0	382.0	478.0

* Smaller radius curves can always be made by cutting or using pipe of shorter lengths.

† The angle of deflection between successive pipe centerlines obtained at each joint is approximately 4 deg. for pipe sizes up to and including 24 in., and 3 deg. for 30- and 36-in. pipe.

‡ Pipe lengths are considered as chords and each field joint as a point on the curve.

§ To find the radius for any pipe length not shown and for any given degrees of deflection, multiply the figure in column 2, opposite the given degrees of deflection, by the length of the pipe section. Another method, where the length of pipe section is in whole feet, is to total figures in various columns which add up to the length desired. For example, to find the radius for 36-ft. long sections at 3°00′ deflection: opposite 3°00′ add figures in columns 6, 3 and 2. Radius equals 687.6 ft.

measurement. Table 26 is provided as a convenient and standard means of converting the horizontal distance to length on the pipe centerline. An example will illustrate the use of the table.

The slope distance is required where the horizontal distance is 489.56 ft. and the slope is designated as 12 ft. per 100 ft. rise (i.e., a grade of 12 per cent, or 6° 50.6′). Opposite 12 in column 2

TABLE 25

*Deflection of Pipe F for Standard Dresser Couplings and Straight Sections of Pipe for Various Degrees of Deflection at Each Joint**

(See Fig. 8)

1	2	3	4	5	6	7	8
	Length of Pipe Section—*ft.*†						
Deflection *D*	*L* = 1	*L* = 5	*L* = 10	*L* = 20	*L* = 30	*L* = 40	*L* = 50
	Deflection of Pipe *F*‡						
0°15′	0′ 1/16″	0′ 1/4″	0′ 1/2″	0′1 1/16″	0′1 9/16″	0′2 1/16″	0′2 5/8″
30′	0′ 1/8″	0′ 1/2″	0′1 1/16″	0′2 1/8″	0′3 1/8″	0′4 3/16″	0′5 1/4″
45′	0′ 3/16″	0′ 13/16″	0′1 9/16″	0′3 1/8″	0′4 3/4″	0′6 5/16″	0′7 7/8″
1°00′	0′ 3/16″	0′1 1/16″	0′2 1/16″	0′4 3/16″	0′6 5/16″	0′8 3/8″	0′10 1/2″
15′	0′ 1/4″	0′1 5/16″	0′2 5/8″	0′5 1/4″	0′7 7/8″	0′10 7/16″	1′1 1/16″
30′	0′ 5/16″	0′1 9/16″	0′3 1/8″	0′6 5/16″	0′9 7/16″	1′ 9/16″	1′3 3/4″
45′	0′ 3/8″	0′1 13/16″	0′3 11/16″	0′7 5/16″	0′11″	1′2 11/16″	1′6 5/16″
2°00′	0′ 7/16″	0′2 1/16″	0′4 3/16″	0′8 3/8″	1′ 9/16″	1′4 3/4″	1′8 15/16″
15′	0′ 1/2″	0′2 3/8″	0′4 11/16″	0′9 7/16″	1′2 1/8″	1′6 7/8″	1′11 9/16″
30′	0′ 9/16″	0′2 5/8″	0′5 1/4″	0′10 1/2″	1′3 11/16″	1′8 15/16″	2′2 3/16″
45′	0′ 9/16″	0′2 7/8″	0′5 3/4″	0′11 1/2″	1′5 1/4″	1′11″	2′4 13/16″
3°00′	0′ 5/8″	0′3 1/8″	0′6 1/4″	1′ 9/16″	1′6 13/16″	2′1 1/8″	2′7 7/16″
15′	0′ 11/16″	0′3 3/8″	0′6 13/16″	1′1 5/8″	1′8 7/16″	2′3 3/16″	2′10″
30′	0′ 3/4″	0′3 11/16″	0′7 5/16″	1′2 5/8″	1′10″	2′5 5/16″	3′ 5/8″
45′	0′ 13/16″	0′3 15/16″	0′7 7/8″	1′3 11/16″	1′11 9/16″	2′7 3/8″	3′3 1/4″
4°00′	0′ 13/16″	0′4 3/16″	0′8 3/8″	1′4 3/4″	2′1 1/8″	2′9 1/2″	3′5 7/8″
15′	0′ 7/8″	0′4 7/16″	0′8 7/8″	1′5 13/16″	2′2 11/16″	2′11 9/16″	3′8 7/16″
30′	0′ 15/16″	0′4 11/16″	0′9 7/16″	1′6 13/16″	2′4 1/4″	3′1 11/16″	3′11 1/16″
45′	0′1″	0′4 15/16″	0′9 15/16″	1′7 7/8″	2′5 13/16″	3′3 3/4″	4′1 11/16″
5°00′	0′1 1/16″	0′5 1/4″	0′10 7/16″	1′8 15/16″	2′7 3/8″	3′5 13/16″	4′4 5/16″
15′	0′1 1/8″	0′5 1/2″	0′11″	1′9 15/16″	2′8 15/16″	3′7 15/16″	4′6 7/8″
30′	0′1 1/8″	0′5 3/4″	0′11 1/2″	1′11″	2′10 1/2″	3′10″	4′9 1/2″
45′	0′1 3/16″	0′6″	1′0″	2′ 1/16″	3′ 1/16″	4′ 1/16″	5′ 1/8″
6°00′	0′1 1/4″	0′6 1/4″	1′ 9/16″	2′1 1/16″	3′1 5/8″	4′2 3/16″	5′2 11/16″

* The angle of deflection between successive pipe centerlines obtained at each joint is approximately 4 deg. for pipe sizes up to and including 24 in. and 3 deg. for 30- and 36-in. pipe.

† Pipe lengths are considered as chords and each field joint as a point on the curve.

‡ To find the deflection for any pipe length not shown and for any given degrees of deflection, multiply the figure in column 2, opposite given deflection, by length of pipe section. A more accurate method, where the length of the pipe section is in whole feet, is to total figures in various columns which add up to the length desired. For example, to find the deflection for 36-ft. long sections at 3°00′ deflection: opposite 3°00′ add figures in columns 6, 3 and 2. Deflection equals 1′10 9/16″.

find 0.007174 in column 4. Then multiplying, $0.007174 \times 489.56 = 3.51$;

489.56	horizontal distance
3.51	correction
493.07	slope distance

Interpolation can be made for any fraction of a foot, such as 12.56 ft. rise per 100 ft. horizontal. Compared with actual computation, the error by interpolation is very small. For instance, if the rise per 100 ft. is given as 32.5,

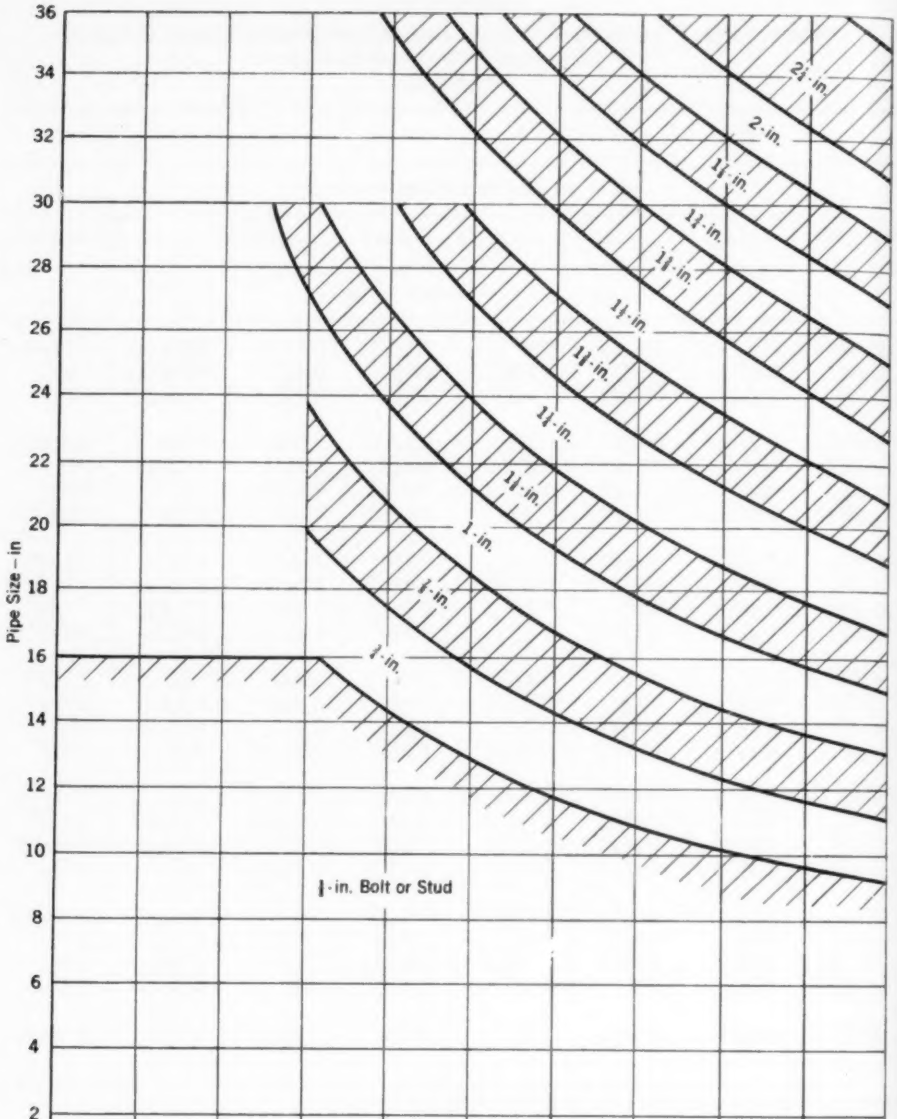

FIG. 10. Diameters of Joint Harness Tie-Bolts, or Studs, for Given Pipe Sizes and Operating Pressures *

* The bolt size shown in a strip area may be used for any combination of pipe size and pressure lines intersecting in that area.

the number to be added to each foot of horizontal distance is 0.051498 by interpolation and 0.051487 by computation. This means that for every 1,000 ft. of horizontal distance, there is an error by interpolation of 0.01 ft., or $\frac{1}{8}$ in. This difference also applies, approximately, to the values of that portion of the table dealing with flatter slopes.

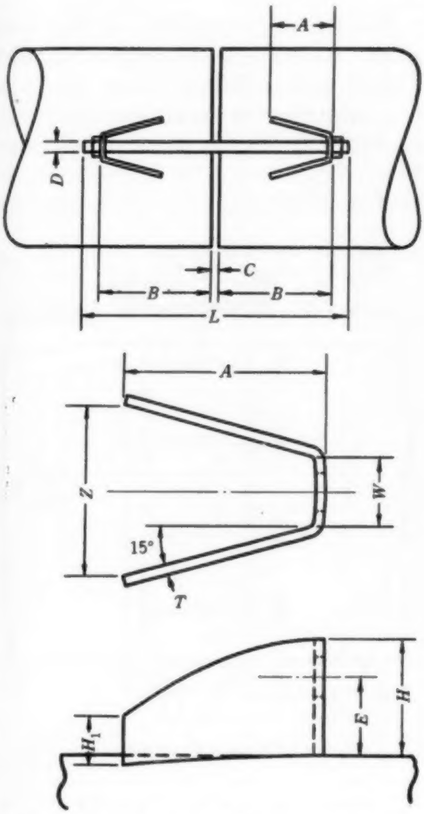

FIG. 11. Details of Joint Harness Tie-Bolts, or Studs, and Lugs

If the slope is shown only by elevations at the points of change in grade, the table may be used thus: secure from the profile the difference in elevation between the ends of the slope considered; the slope per foot is obtained by dividing this value by the horizontal distance. (The quotient also represents the tangent of the angle of slope.) Once the slope per foot is obtained, the procedure is the same as in the example above.

The use of Tables 24, 25 and 26 provides a basis for agreement between layout men and checkers when accuracy is required or desired. Without such tables minor disagreements continually arise, which necessitate expensive changes in drawings and prints to compose insignificant differences.

FIG. 12. Dresser Harness Coupling

Joint Harness for Dresser Couplings

Dresser couplings are ordinarily installed and perform satisfactorily without the necessity of restraining the joints. However, on unanchored bends, and in other situations where cumulative movement through the Dresser coupling must be prevented, a

TABLE 26

Additive Values for Computing Slope From Horizontal Distance

Slope Designation			Value to Be Added per Foot of Horizontal Distance
Rise or Fall—*ft.*		Angle of Slope	
Per Horiz. Foot	Per 100 ft. Horiz.*		
0.0100	1.00	0° 34.4′	0.000050
0.0200	2.00	1° 08.8′	0.000200
0.0300	3.00	1° 43.1′	0.000450
0.0400	4.00	2° 17.4′	0.000800
0.0500	5.00	2° 52.8′	0.001249
0.0600	6.00	3° 26.0′	0.001798
0.0700	7.00	4° 00.2′	0.002447
0.0800	8.00	4° 34.4′	0.003195
0.0900	9.00	5° 08.6′	0.003990
0.1000	10.00	5° 42.6′	0.004988
0.1100	11.00	6° 16.6′	0.006032
0.1200	12.00	6° 50.6′	0.007174
0.1300	13.00	7° 24.4′	0.008415
0.1400	14.00	7° 58.2′	0.009752
0.1500	15.00	8° 31.8′	0.011187
0.1600	16.00	9° 05.4′	0.012719
0.1700	17.00	9° 38.9′	0.014347
0.1800	18.00	10° 12.2′	0.016071
0.1900	19.00	10° 45.5′	0.017890
0.2000	20.00	11° 18.6′	0.019804
0.2100	21.00	11° 51.6′	0.021812
0.2200	22.00	12° 24.5′	0.023914
0.2300	23.00	12° 57.2′	0.026109
0.2400	24.00	13° 29.7′	0.028399
0.2500	25.00	14° 02.3′	0.030776
0.2600	26.00	14° 34.5′	0.033247
0.2700	27.00	15° 06.6′	0.035808
0.2800	28.00	15° 38.5′	0.038460
0.2900	29.00	16° 10.3′	0.041201
0.3000	30.00	16° 42.0′	0.044031
0.3100	31.00	17° 13.4′	0.046948
0.3200	32.00	17° 44.7′	0.049952
0.3300	33.00	18° 15.8′	0.053043

* Also per cent grade.

joint harness may be provided. Such a harness is illustrated in Fig. 9.

The diameters of joint harness tie-bolts, or studs, to be used for given pipe sizes and operating pressures can be obtained by the use of Fig. 10. The dimensions of lugs and details of joint assemblies for given diameters of tie-bolts may be ascertained from Fig. 11 and Table 27.

Dresser Harness Couplings

The harness coupling is a "universal joint" arrangement (Fig. 12, 13). The pipe may deflect in any plane, yet it maintains a positive connection against full design stress at all times. It is recommended for intake lines and similar installations. Job requirements

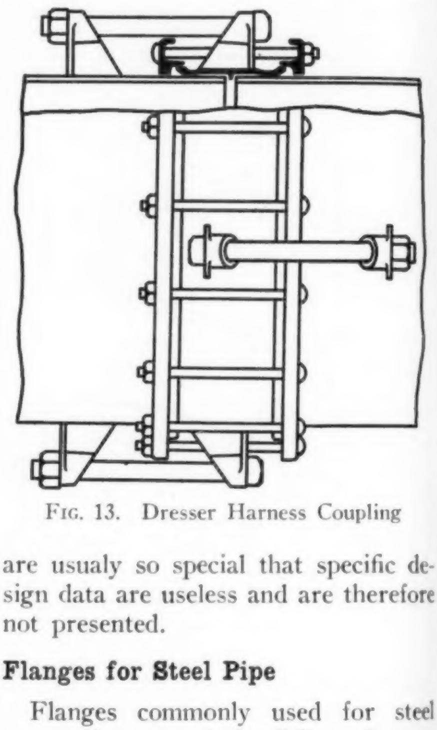

FIG. 13. Dresser Harness Coupling

are usualy so special that specific design data are useless and are therefore not presented.

Flanges for Steel Pipe

Flanges commonly used for steel water pipe are of the "slip-on" type. Flanges may be of several classes:

1. Steel ring, a hubless flange which is made from rolled plate, billet or curved flat.

2. Cast steel, usually made with a low welding hub.

3. Forged steel, made with a low hub, or with a welding neck, by a rolling or forging process.

The welding-neck type of flange is really not justified for the comparatively low pressures usually found in water works service.

Steel Ring Flanges

Recent studies and experiments (14) conducted on full-size steel ring flanges with cloth-inserted rubber gaskets demonstrate that satisfactorily tight joints can be obtained using the thicknesses shown in Table 28.

The drilling template for steel ring flanges, whose dimensional standards are given in Table 28, matches the drilling templates of the 125-lb. cast-iron standard and also the ASA 150-lb. standard which is the same as the 125-lb. cast-iron standard. It is not necessary, however, when using Class 75 and Class 150 ring steel flanges to employ bolts larger than those given in the table. If connections are being made to American Standard drilled flanges, washers may be used to cover the larger holes so that the smaller bolts will hold satisfactorily.

Steel ring flanges have been designed for use with 1/16-in. thick cloth-inserted rubber gaskets. The gaskets should be comparatively narrow and occupy the surface of the flange between the bolt holes and the inside diameter of the pipe or flange. Nothing is gained by enlarging the gasket.

Both the size of the gasket and the type of gasket material are integral and controlling factors in the design of a bolted joint. Gasket recommendations should be observed, therefore, to achieve best results.

TABLE 27

*Dimensions of Joint Harness Tie-Bolts, or Studs, and Lugs for Style 38 Dresser Couplings**
(See Fig. 11)

Stud Diam. *D*	*A*	*W*	*Z*	*T*	*H*	*E*	H_1	Hole Diam.	5-in. Middle Ring		7-in. Middle Ring	
									L†	*B*†	*L*†	*B*†
5/8	3	1 1/2	2 7/8	3/8	3 7/8	3	2	3/4	22 1/4	9 1/2	23 1/2	10 1/8
3/4	3 3/4	1 11/16	3 1/2	3/8	4 1/8	3 1/8	2	7/8	24	10 1/4	25 3/4	11 1/8
7/8	4 1/2	1 15/16	4 3/16	3/8	4 1/4	3 1/8	2	1	25 3/4	11	27	11 5/8
1	5 1/8	2 1/8	4 11/16	3/8	4 1/2	3 1/4	2	1 1/8	27 1/4	11 5/8	29	12 1/2
1 1/8	6 1/8	2 3/8	6 5/8	1/2	4 3/4	3 5/8	2 1/2	1 1/4	10-in. Middle Ring		31 1/4	13 1/2
1 1/4	6 3/4	2 9/16	5 11/16	1/2	5	3 3/4	2 1/2	1 3/8	36	15 3/4	32 1/2	14
1 3/8	7 1/2	2 13/16	7	1/2	5 3/8	3 3/4	2 1/2	1 1/2	37 1/2	16 3/8	33 3/4	14 1/2
1 1/2	8 3/4	3	7 1/2	1/2	5 1/2	3 7/8	2 1/2	1 5/8	40 1/2	17 3/4	37	16
1 5/8	9 1/2	3 1/4	8 1/8	1/2	5 5/8	3 7/8	2 1/2	1 3/4	42 1/4	18 1/2	39	16 7/8
1 3/4	10 1/8	3 7/16	8 5/8	1/2	5 7/8	4	2 1/2	1 7/8	43 1/4	18 7/8	40	17 1/4
1 7/8	11	3 11/16	9 1/2	1/2	6	4	2 1/2	2	45 3/4	20	42 1/4	18 1/4
2	12 1/8	3 7/8	9 15/16	3/4	6 1/4	4 1/4	2 1/2	2 1/8	48 1/2	21 1/4	45 1/4	19 5/8
2 1/4	14 1/4	4 5/16	11 1/2	3/4	6 3/4	4 5/16	2 1/2	2 3/8	53	23 1/4	50 1/2	22

* All dimensions are in inches. Bolt, or stud, sizes are based on the use of two bolts, or studs, and four lugs per joint. Maximum bolt stress is approximately 40,000 psi. Use heat-treated bolts with yield strength of approximately 70,000 psi.

† Dimensions *L* and *B* are based on a *C* value of 1 in. For values of *C* greater than 1 in., *B* must be decreased.

Cast-Steel Flanges

A comparatively heavy cast-steel flange (but thinner than the American

Standard) has been satisfactorily used for many years to join steel pipe to flanged cast-iron pipe, valves, pumps or other accessories. These flanges have the same inside diameter, the same outside diameter and the same drilling template used on the 125-lb. standard cast-iron flange. Dimensional standards for this slip-on type of flange are given in Table 29.

TABLE 28

Dimensional Standards for Steel Ring Flanges
Sizes 6–36 in.

1	2	3	4	5	6	7	8	9
Pipe o.d. *in.*	Pipe Wall Thickness *in.*	Flange o.d. *in.*	Bolt Circle Diam. *in.*	No. of Bolts	Bolt Diam. *in.*	Gasket o.d. *in.*	Commercial Flange Thickness—*in.*	
							75 psi.	150 psi.
6⅝	0.172	11	9½	8	⅝	8¾	11/16	11/16
8⅝	0.172	13½	11¾	8	¾	11	11/16	11/16
10¾	0.188	16	14¼	12	¾	13⅜	11/16	11/16
12¾	0.188	19	17	12	⅞	16⅛	1⅛	1⅜
14	0.188	21	18¾	12	1	17¾	1⅛	1⅜
16	0.188	23½	21¼	16	1	20¼	1⅛	1⅜
18	0.188	25	22¾	16	1	21⅝	1⅛	1⅜
20	0.188	27½	25	20	1	23⅞	1⅛	1⅜
22	0.218	29½	27¼	20	1	26	1⅛	1⅜
24	0.218	32	29½	20	1	28¼	1⅜	1¾
26	0.250	34¼	31¾	24	1	30½	1⅜	1¾
28	0.250	36½	34	28	1	32¾	1⅜	1¾
30	0.250	38¾	36	28	1	34½	1⅜	1¾
32	0.281	41¾	38½	28	1	37	1⅜	1¾
34	0.281	43¾	40½	32	1	39	1⅜	1¾
36	0.313	46	42¾	32	1	41¼	1⅜	1¾

Forged-Steel Flanges

The American Standards Association Standard for Steel Pipe Flanges and Flanged Fittings (ASA B16e–1939) provides dimensions for American Standard steel flanges. These are given for sizes up to and including 24 in. for several primary pressure ratings. Dimensions for flanges with primary ratings of 150 psi. and 300 psi. are given in Tables 30 and 31. Notice that the cold water non-shock working pressure rating for these flanges is much higher than their primary service rating. This is because the primary service rating is conditioned upon operational temperatures at 500° F. in the case of the 150-lb. flange and 750° F. in the case of the 300-lb. flange.

Field-welded Joints

In cases where enamel-lined steel pipe is used, 24 in. is the smallest size which should be field welded. This is the smallest pipe which an operator can enter for the purpose of enameling the inside at the welded joint.

Either large or small pipe can be field welded when there is no inside coating to be manually applied at the joint.

Several kinds of field-welded joints are satisfactory:

1. Single-welded butt joint
2. Double-welded butt joint
3. Single-welded slip joint
4. Double-welded slip joint
5. Butt-strap joint

TABLE 29

*Dimensional Standards for Cast-Steel Slip-on Flanges to Match 125-lb. Cast-Iron Standard**

1	2	3	4	5	6	7	8	9	10
						Drilling Template			
Nominal Size *in.*	Flange o.d. *in.*	Flange Thickness *in.*	Flange i.d. *in.*	Hub o.d. *in.*	Hub Length† *in.*	No. of Bolts	Diam. of Bolt *in.*	Bolt Circle *in.*	Approx. Weight (ea.) *lb.*
6	11	$\frac{9}{16}$	$6\frac{1}{8}$	$6\frac{3}{4}$	$1\frac{1}{16}$	8	$\frac{3}{4}$	$9\frac{1}{2}$	10
$6\frac{5}{8}$	11	$\frac{9}{16}$	$6\frac{3}{4}$	$7\frac{3}{8}$	$1\frac{1}{16}$	8	$\frac{3}{4}$	$9\frac{1}{2}$	10
8	$13\frac{1}{2}$	$\frac{9}{16}$	$8\frac{1}{8}$	$8\frac{3}{4}$	$1\frac{1}{16}$	8	$\frac{3}{4}$	$11\frac{3}{4}$	14
$8\frac{5}{8}$	$13\frac{1}{2}$	$\frac{9}{16}$	$8\frac{3}{4}$	$9\frac{3}{8}$	$1\frac{1}{16}$	8	$\frac{3}{4}$	$11\frac{3}{4}$	14
10	16	$\frac{5}{8}$	$10\frac{1}{8}$	$10\frac{7}{8}$	$1\frac{1}{8}$	12	$\frac{7}{8}$	$14\frac{1}{4}$	20
$10\frac{3}{4}$	16	$\frac{5}{8}$	$10\frac{7}{8}$	$11\frac{5}{8}$	$1\frac{1}{8}$	12	$\frac{7}{8}$	$14\frac{1}{4}$	20
12	19	$\frac{11}{16}$	$12\frac{1}{8}$	$12\frac{7}{8}$	$1\frac{3}{16}$	12	$\frac{7}{8}$	17	30
$12\frac{3}{4}$	19	$\frac{11}{16}$	$12\frac{7}{8}$	$13\frac{1}{16}$	$1\frac{3}{16}$	12	$\frac{7}{8}$	17	30
14	21	$\frac{11}{16}$	$14\frac{1}{8}$	$14\frac{7}{8}$	$1\frac{3}{16}$	12	1	$18\frac{3}{4}$	41
16	$23\frac{1}{2}$	$\frac{11}{16}$	$16\frac{1}{8}$	$16\frac{7}{8}$	$1\frac{3}{16}$	16	1	$21\frac{1}{4}$	44
18	25	$\frac{11}{16}$	$18\frac{1}{8}$	$18\frac{15}{16}$	$1\frac{3}{16}$	16	$1\frac{1}{8}$	$22\frac{3}{4}$	46
20	$27\frac{1}{2}$	$\frac{3}{4}$	$20\frac{1}{8}$	$21\frac{1}{16}$	$1\frac{1}{4}$	20	$1\frac{1}{8}$	25	61
22	$29\frac{1}{2}$	$\frac{3}{4}$	$22\frac{1}{8}$	$23\frac{1}{8}$	$1\frac{1}{4}$	20	$1\frac{1}{4}$	$27\frac{1}{4}$	63
24	32	$\frac{13}{16}$	$24\frac{1}{8}$	$25\frac{1}{8}$	$1\frac{5}{16}$	20	$1\frac{1}{4}$	$29\frac{1}{2}$	82
26	$34\frac{1}{4}$	1	$26\frac{1}{8}$	$27\frac{3}{8}$	2	24	$1\frac{1}{4}$	$31\frac{3}{4}$	110
28	$36\frac{1}{2}$	1	$28\frac{1}{8}$	$29\frac{3}{8}$	2	28	$1\frac{1}{4}$	34	151
30	$38\frac{3}{4}$	1	$30\frac{1}{8}$	$31\frac{1}{2}$	2	28	$1\frac{1}{4}$	36	159
32	$41\frac{3}{4}$	$1\frac{1}{8}$	$32\frac{1}{8}$	$33\frac{3}{4}$	$2\frac{1}{8}$	28	$1\frac{1}{2}$	$38\frac{1}{2}$	190
34	$43\frac{3}{4}$	$1\frac{1}{8}$	$34\frac{1}{8}$	$35\frac{3}{4}$	$2\frac{1}{8}$	32	$1\frac{1}{2}$	$40\frac{1}{2}$	200
36	46	$1\frac{1}{8}$	$36\frac{1}{8}$	$37\frac{3}{4}$	$2\frac{1}{8}$	32	$1\frac{1}{2}$	$42\frac{3}{4}$	208

* For 125 psi. cold water non-shock working pressure.
† Distance from face of flange to end of hub.

A.W.W.A. Standard Specification 7A.8–T (15) fully covers the requirements to produce satisfactory field welding.

Line tension is avoided in a welded pipeline by providing a Dresser coupling or a welded slip joint at intervals of about 400 or 500 ft. The slip joint for this purpose is not welded in sequence with the butt welds between individual pipe lengths. After the 400- or 500-ft. field sections between slip joints have been welded, and when the temperature is lowest (so that the length of pipe between slip joints is shortest), the unwelded slip joints back of the last completed field section are welded.

The result of this method is to place a compression in the pipeline as soon as the temperature rises above that at which the slip joints were welded. It has been demonstrated that the longitudinal compression is not injurious to the pipe although the thrust of such compression must be relieved by expansion joints adjacent to valves, pumps, structural walls or other similar installations. (See Fig. 19, 27 and 37.)

TABLE 30

*Dimensions of American Standard Steel Flanges for 150-psi. (Gage) Primary Service Pressure Rating**

1	2	3	4	5	6	7
Nominal Pipe Size *in.*	Flange o.d. *in.*	Min. Thickness of Flange *in.*	Hub Diam. *in.*	Bolt Circle Diam. *in.*	No. of Bolts	Bolt Size *in.*
$\frac{1}{2}$	$3\frac{1}{2}$	$\frac{7}{16}$	$1\frac{3}{16}$	$2\frac{3}{8}$	4	$\frac{1}{2}$
$\frac{3}{4}$	$3\frac{7}{8}$	$\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{3}{4}$	4	$\frac{1}{2}$
1	$4\frac{1}{4}$	$\frac{9}{16}$	$1\frac{15}{16}$	$3\frac{1}{8}$	4	$\frac{1}{2}$
$1\frac{1}{4}$	$4\frac{5}{8}$	$\frac{5}{8}$	$2\frac{5}{16}$	$3\frac{1}{2}$	4	$\frac{1}{2}$
$1\frac{1}{2}$	5	$\frac{11}{16}$	$2\frac{9}{16}$	$3\frac{7}{8}$	4	$\frac{1}{2}$
2	6	$\frac{3}{4}$	$3\frac{1}{16}$	$4\frac{3}{4}$	4	$\frac{5}{8}$
$2\frac{1}{2}$	7	$\frac{7}{8}$	$3\frac{9}{16}$	$5\frac{1}{2}$	4	$\frac{5}{8}$
3	$7\frac{1}{2}$	$\frac{15}{16}$	$4\frac{1}{4}$	6	4	$\frac{5}{8}$
$3\frac{1}{2}$	$8\frac{1}{2}$	$\frac{15}{16}$	$4\frac{13}{16}$	7	8	$\frac{5}{8}$
4	9	$\frac{15}{16}$	$5\frac{5}{16}$	$7\frac{1}{2}$	8	$\frac{5}{8}$
5	10	$\frac{15}{16}$	$6\frac{7}{16}$	$8\frac{1}{2}$	8	$\frac{3}{4}$
6	11	1	$7\frac{9}{16}$	$9\frac{1}{2}$	8	$\frac{3}{4}$
8	$13\frac{1}{2}$	$1\frac{1}{8}$	$9\frac{11}{16}$	$11\frac{3}{4}$	8	$\frac{3}{4}$
10	16	$1\frac{3}{16}$	12	$14\frac{1}{4}$	12	$\frac{7}{8}$
12	19	$1\frac{1}{4}$	$14\frac{3}{8}$	17	12	$\frac{7}{8}$
14 o.d.	21	$1\frac{3}{8}$	$15\frac{3}{4}$	$18\frac{3}{4}$	12	1
16 o.d.	$23\frac{1}{2}$	$1\frac{7}{16}$	18	$21\frac{1}{4}$	16	1
18 o.d.	25	$1\frac{9}{16}$	$19\frac{7}{8}$	$22\frac{3}{4}$	16	$1\frac{1}{8}$
20 o.d.	$27\frac{1}{2}$	$1\frac{11}{16}$	22	25	20	$1\frac{1}{8}$
24 o.d.	32	$1\frac{7}{8}$	$26\frac{1}{8}$	$29\frac{1}{2}$	20	$1\frac{1}{4}$

* 230-psi. cold water non-shock working pressure.

Victaulic Couplings

The Victaulic coupling is a bolted, segmental, clamp-type, mechanical coupling whose housing encloses a U-shaped rubber gasket. The housing locks the pipe ends together to prevent end movement, yet allows some degree of flexiblity in alignment. The rubber gasket is tight under either pressure or vacuum service.

Table 32, together with its associated Fig. 14, gives the over-all dimensions of some common sizes.

Ends of pipe must be specially prepared to accommodate Victaulic couplings. This is done by grooving, banding or welding adaptors to pipe ends.

Figure 15 shows an adaptor ring butt-welded to the pipe end. Figure 16 shows a slip-on type of adaptor sometimes used. Table 33 gives dimensional data relative to pipe-end preparation, permissible deflection at joints and pressure rating.

A different kind of end preparation is frequently used for pipe of larger diameter. A steel band is attached to the pipe end, using one fillet weld as shown in Fig. 17, or two fillet welds as shown in Fig. 18. Table 34 gives data for the larger pipe when bands are used

TABLE 31

*Dimensions of American Standard Steel Flanges for 300-psi. (Gage) Primary Service Pressure Rating**

1	2	3	4	5	6	7
Nominal Pipe Size *in.*	Flange o.d. *in.*	Min. Thickness of Flange *in.*	Hub Diam. *in.*	Bolt Circle Diam. *in.*	No. of Bolts	Bolt Size *in.*
½	3¾	9/16	1½	2⅝	4	½
¾	4⅝	⅝	1⅞	3¼	4	⅝
1	4⅞	11/16	2⅛	3½	4	⅝
1¼	5¼	¾	2½	3⅞	4	⅝
1½	6⅛	13/16	2¾	4½	4	¾
2	6½	⅞	3 5/16	5	8	⅝
2½	7½	1	3 15/16	5⅞	8	¾
3	8¼	1⅛	4⅝	6⅝	8	¾
3½	9	1 3/16	5¼	7¼	8	¾
4	10	1¼	5¾	7⅞	8	¾
5	11	1⅜	7	9¼	8	¾
6	12½	1 7/16	8⅛	10⅝	12	¾
8	15	1⅝	10¼	13	12	⅞
10	17½	1⅞	12⅝	15¼	16	1
12	20½	2	14¾	17¾	16	1⅛
14 o.d.	23	2⅛	16¾	20¼	20	1⅛
16 o.d.	25½	2¼	19	22½	20	1¼
18 o.d.	28	2⅜	21	24¾	24	1¼
20 o.d.	30½	2½	23⅛	27	24	1¼
24 o.d.	36	2¾	27⅝	32	24	1½

* 500-psi. cold water non-shock working pressure.

such as are shown in Fig. 17 and 18. Deflection data and pressure rating are given for the larger couplings.

When using slip-on bands, notice that the outside diameter and groove details of the band must accommodate standard-size couplings, and that the inside diameter must fit the o.d. of standard-size steel pipe. These requirements fix the band thickness.

Victaulic couplings are manufactured in other sizes for use with cast-iron pipe. These sizes can be, and frequently are, used on steel pipe also. The design of the adaptor end then becomes a special case, however.

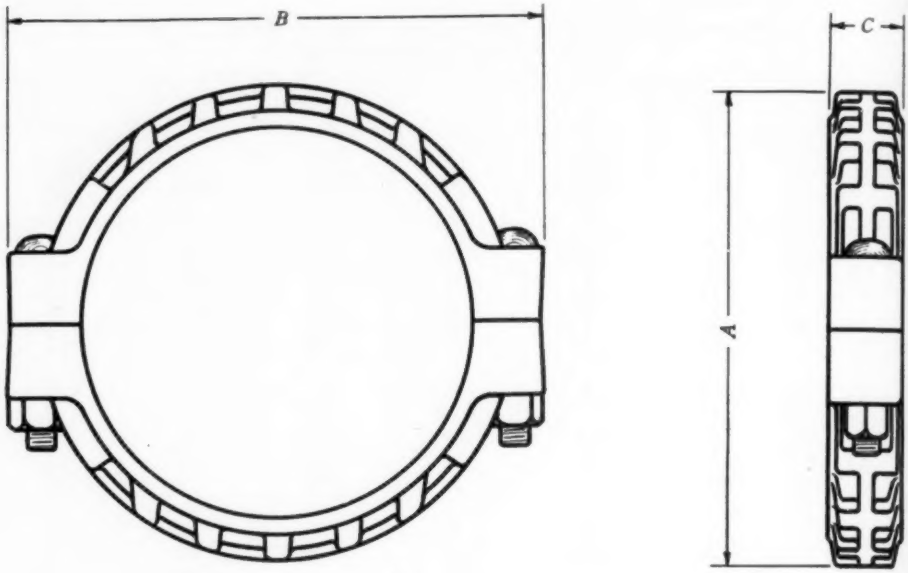

Fig. 14. Victaulic Coupling

Expansion Joints

Unrestrained steel pipe expands or contracts about $\frac{3}{4}$ in. per 100 ft. of pipe for each 100° F. change in temperature.

The expansion and contraction of steel pipe laid underground is amply cared for by Dresser couplings without detriment to pipe, couplings or gaskets.

In field-welded lines expansion and contraction is cared for while the joints are being made. (See Field-welded Joints.)

Forces due to expansion and contraction should not be allowed to reach valves, pumps or similar appurtenances to which damage might be done. This condition can be avoided by making the pipeline connection using an expansion joint or Dresser couplings or by providing anchor rings and thrust blocks of sufficient size and weight to prevent forces reaching the parts to be protected.

Expansion and contraction must be cared for on exposed lines. When Dresser couplings are used for field joints, they will ordinarily provide for enough movement if individual pipe

TABLE 32

Dimensions of Victaulic Couplings
(See Fig. 14)

Pipe Size o.d. *in.*	Dimensions—*in.*		
	A	*B*	*C*
6 5/8	9	11 1/8	2
8 5/8	11 3/8	13 7/8	2 3/8
10 3/4	13 1/2	16	2 1/2
12 3/4	15 1/2	18	2 1/2
14	16 5/8	18 7/8	2 3/4
16	19	22 1/8	2 7/8
18	21 1/4	24 3/4	3
20	23 1/2	27 1/8	3
24	27 5/8	31	3 1/8

TABLE 33

Adaptor End Dimensions, Joint Deflection Data and Strength Data for Victaulic Coupling Sizes 6–24 in.
(See Fig. 15, 16)

1	2	3	4	5	6	7	8
Pipe o.d. *in.*	Dimensions—*in.*				Max. Deflection at Joint	Press. Rating *psi.*	End Pull Strength *lb.*
	A	*B*	*C*	*L* (Min.)			
6 5/8	5/8	3/8	6.455	2	2°10′	1,000	125,000
8 5/8	3/4	7/16	8.441	2 1/2	1°40′	800	170,000
10 3/4	3/4	1/2	10.562	2 1/2	1°20′	800	210,000
12 3/4	3/4	1/2	12.531	2 1/2	1°7′	800	250,000
14	15/16	1/2	13.781	2 1/2	1°2′	300	
16	15/16	1/2	15.781	2 1/2	0°54′	300	
18	1	1/2	17.781	2 1/2	0°48′	300	
20	1	1/2	19.781	2 1/2	0°43′	300	
24	1	9/16	23.656	3	0°36′	300	

sections are anchored, so that expansion or contraction is not cumulative over several lengths.

Expansion joints in pipe on bridges should be at points where the bridge structure itself contains expansion joints.

On field-welded lines, expansion joints may be located midway between anchors if the pipeline is laid level. On slopes, the joint is usually best placed adjacent to, and on the downhill side of, the anchor point. Pipe ordinarily offers great resistance to movement uphill. Therefore the strength of the pipe at the anchor block should be investigated to be sure that it is adequate to resist the downhill thrust. The spacing and positioning of expansion joints should be governed by site and profile requirements.

On pipe in the size range 6–36 in. inclusive, a slip joint or stuffing-box type of expansion joint is most frequently used (Fig. 19). Dimensional data for some sizes are given in Table 35.

The packing may consist of alternate split rings of rubber compound and jute, or jute rings may be used alone.

The stuffing-box expansion joint is sometimes made double-ended. Limited movement features are also added to both the single- and double-ended types. Figure 20 illustrates the double-ended joint with limited movement feature.

When installing an expansion joint, the initial setting should be established with due regard to the then existing temperature and pipe length.

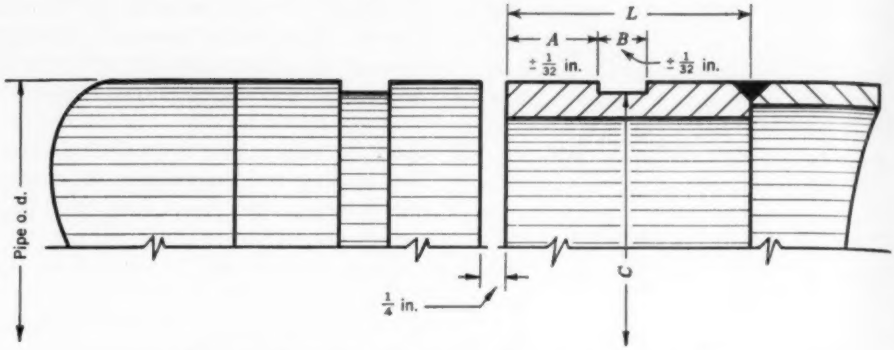

FIG. 15. Victaulic Adaptor Butt-welded to Pipe End (Size 24 in. and Smaller)

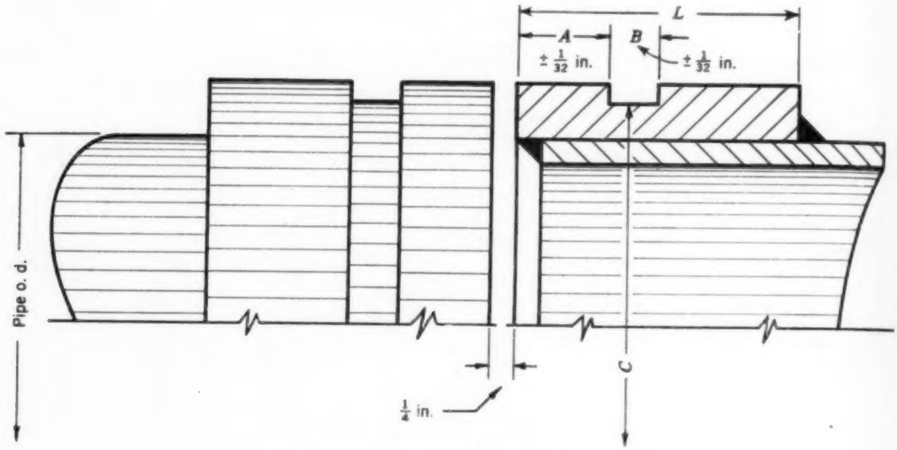

FIG. 16. Victaulic Adaptor Slip-on Type for Pipe (Size 24 in. and Smaller)

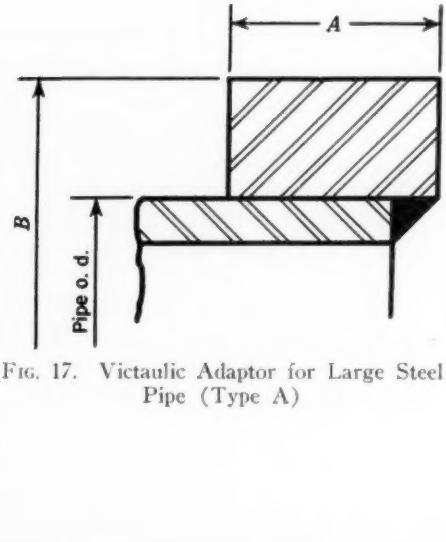

FIG. 17. Victaulic Adaptor for Large Steel Pipe (Type A)

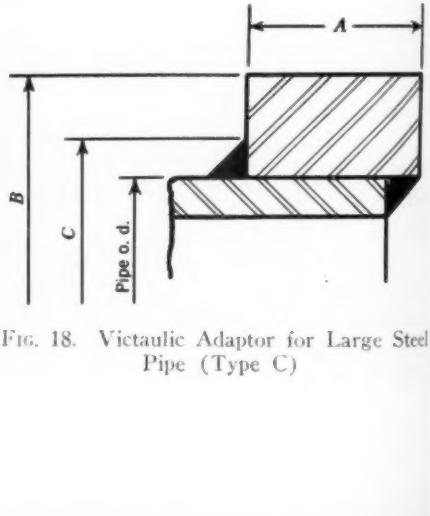

FIG. 18. Victaulic Adaptor for Large Steel Pipe (Type C)

Special Connections

Connection to Cast-Iron Pipe

The best and most economical method of joining steel pipe with cast-iron pipe or hub-end valves is to provide a spigot on the steel pipe. A standard spigot end is shown in Fig. 21. Corresponding dimensional data are given in Table 36.

It is recommended that in all cases spigot ends be provided on steel pipe instead of requiring fabricated bell or hub ends.

TABLE 34

Adaptor End Dimensions, Joint Deflection Data and Pressure Rating for Victaulic Coupling Sizes 26–36 in.
(See Fig. 17, 18)

1	2	3	4	5	6
Pipe o.d. *in.*	Dimensions—*in.*			See Fig. No.	Press. Rating *psi.*
	A	*B*	*C* (Max.)		
26	$1\frac{1}{4}$	$27\frac{1}{8}$		17	175
28	1	$28\frac{7}{8}$		17	150
30	$1\frac{1}{4}$	31		17	150
30	$1\frac{1}{8}$	$31\frac{13}{16}$	$31\frac{1}{8}$	17 or 18	150
32	$1\frac{3}{4}$	33		17	90
32	$1\frac{3}{4}$	$33\frac{3}{4}$	$32\frac{15}{16}$	17 or 18	175
34	$1\frac{3}{4}$	36	$35\frac{1}{4}$	17 or 18	90
36	$1\frac{5}{8}$	38	37	17 or 18	175

Lead, rather than sulfur-containing calking compound, should be used when calking steel pipe.

Connection to Screw-Joint Pipe

In general, when a threaded connection is provided for steel pipe, the size should not exceed 6 in. and should preferably be 4 in. or less. The most efficient and economical method of making the connection is by means of the half-coupling shown in Fig. 22. Associated dimensional data are given in Table 37.

Thredolets provide another means of securing a female thread connection. One is illustrated in Fig. 23 with its dimensional data given in Table 38.

If it actually becomes necessary to tap threads in the side of comparatively thin-wall, large-diameter steel pipe, it may be done as shown in Fig. 24. Sizes and thicknesses of the reinforcing pad are given in Table 39. Table 40 shows the maximum recommended diameters of tapped openings for given sizes of pipe when reinforced with welded pads.

TABLE 35

Dimensions of Single-End Expansion Joint With 10-in. Allowable Movement
(See Fig. 19)

Pipe o.d. *in.*	No. of Bolts	Dimension *A* *in.*
$6\frac{5}{8}$	6	$11\frac{3}{4}$
$8\frac{5}{8}$	6	$13\frac{3}{4}$
$10\frac{3}{4}$	8	$15\frac{7}{8}$
$12\frac{3}{4}$	8	$17\frac{7}{8}$
14	8	$19\frac{1}{2}$
16	10	$21\frac{1}{2}$
18	10	$23\frac{1}{2}$
20	12	$25\frac{1}{2}$
24	14	$29\frac{1}{2}$

Figure 25 shows a method of presenting a male thread connection. A half, or part, of a nipple is welded to the pipe. The thread on this connection should be covered by a cap or thread protector to avoid shipping damage.

A flanged connection for screw-joint pipe is shown in Fig. 26. This is preferable for pipe larger than 6 in. but may be used for any size. Standard threaded or slip-on type companion flanges are used. Dimensions of flanges are given in Tables 30 and 31.

Wall Connections

Steel pipe may pass through, be inserted in, or connected to, concrete walls in several different ways. One method is to use a piece of oversize pipe as a form in the concrete, leaving a hole through which the pipe is later passed. Another is to insert a short, flanged- or plain-end sleeve in the wall when it is poured. Connecting pipe is then attached to the sleeve by means of flanges or Dresser couplings. A pipe section longer than a sleeve may be provided with an anchor ring placed in position when the wall is poured or later cemented in place in an opening left for the purpose.

At pipe entrances flexibility and variable closure distance can be secured by using the whole of a Dresser coupling embedded or cemented in a wall as shown in Fig. 27. If desired, the coupling can be cut in two and neither the follower ring, which is embedded, nor the nonworking half of the center ring need be used.

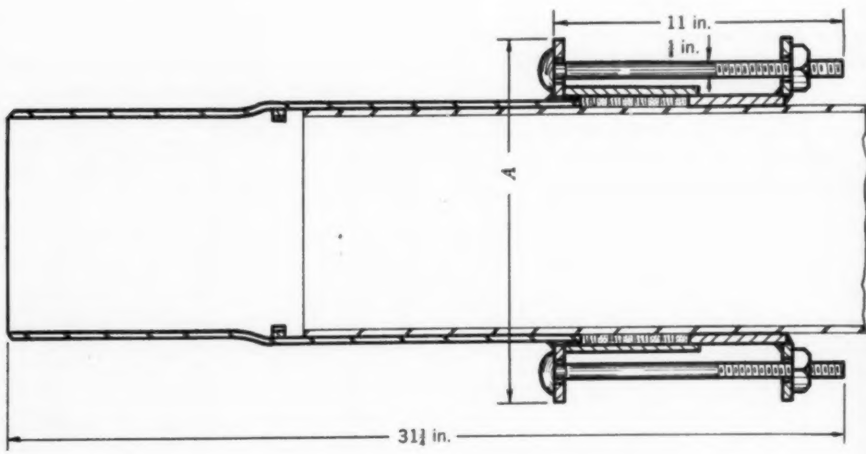

FIG. 19. Slip-Joint, or Stuffing-Box Type Expansion Joint

Fittings

One of the important advantages in using welded-steel pipe is that the problem of fittings may be greatly simplified as compared with other types of piping. Most of the common fittings have been standardized as to dimensions. They may, however, be made integral with runs of straight pipe, or with each other, thus reducing the number of field joints. An example of eliminating unnecessary joints is shown in Fig. 28.

Fittings for Pipe With Flanges or With Plain Ends for Welding

The design of intricate pipe layouts is greatly facilitated by having the center-to-face distance or the center-to-end distance of fittings standardized. Figures 29a and 29b show the most commonly used fittings for flanged-joint pipe. Corresponding ASA dimensions are shown in Table 41.

These same fittings without flanges, but with ends beveled or otherwise

prepared, can be field welded. Dimensions in that case are the same as given in Table 41.

Fittings for Pipe With Dresser Couplings

The dimensions of fittings with ends for Dresser couplings have not been standardized nationally at this writing. However, dimensions for use in good design may be obtained from Fig. 29 and Table 41 by proceeding as follows:

Offsets are simply two elbows made integral, and dimensions marked *V* are variable to suit requirements.

The foregoing dimensions are sufficient to accommodate style 38 Dresser couplings. If other styles of couplings having a longer covering distance are used, or if joint harness or lugs are employed, the foregoing dimensions must be checked for clearance.

Figure 30 shows typical forms of fittings with ends for Dresser couplings.

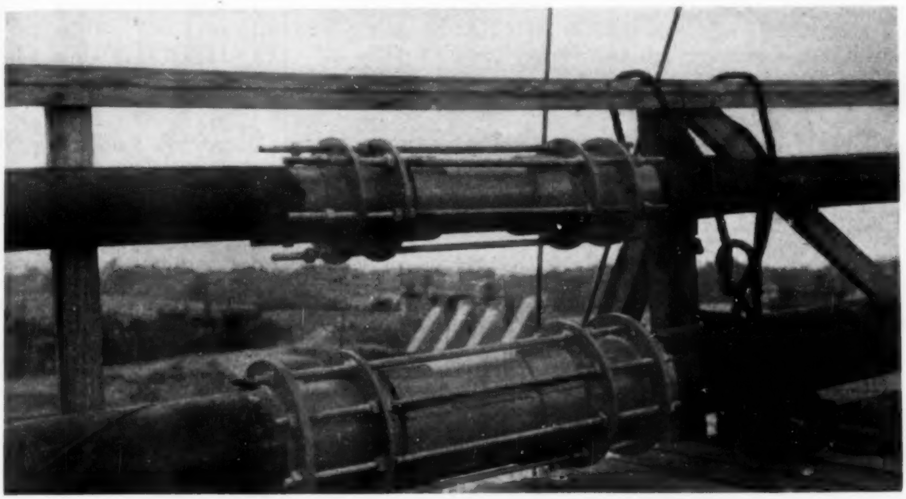

FIG. 20. Slip-Joint, or Stuffing-Box Type Expansion Joint

Elbow center-to-end dimension equals *A, B* or *C,* plus 8 in.

Tee and cross center-to-end dimension equals *A* plus 8 in.

Laterals may develop interference between joints at the crotch. Add 8 in. to *E* and *F on the run;* then develop *E* for the lateral by layout. Use the dimension *E* plus 8 in. until, with a decreasing value of angle *θ*, interference develops.

Reducers have 8 in. of straight pipe added at each end of the reducing portion. Therefore the end-to-end dimension equals *G* plus 16 in.

Deflection at Miter Welds

A.W.W.A. specifications for steel pipe require that when the angular change at miter welds is not specified, it should not exceed 22½ deg. for elbows or curves, or 45 deg. for laterals and wyes. In other fields this maximum has commonly been set at 30 deg., as is shown in Fig. 29 and 30.

There is also a provision in A.W. W.A. Specifications 7A.3 (1) that the minimum chord distance between welds in the throat of elbows and curves must be not less than 12 in. The distance between welds must be less than this

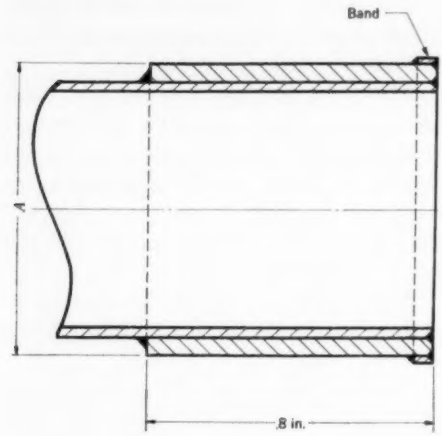

FIG. 21. Spigot End for Joining to Cast-Iron Pipe

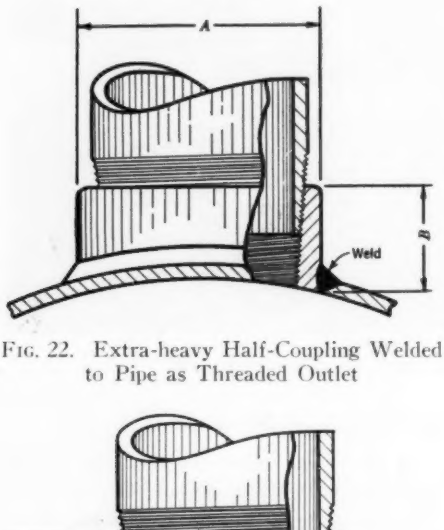

FIG. 22. Extra-heavy Half-Coupling Welded to Pipe as Threaded Outlet

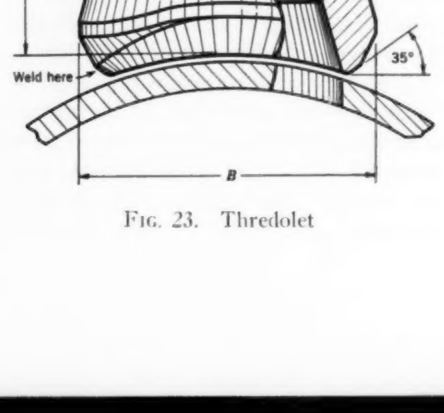

FIG. 23. Thredolet

TABLE 36

*Spigot End Dimensions for Steel Pipe**
(See Fig. 21)

Pipe o.d. *in.*	Spigot Dimensions	
	A *in.*	Band Size *in.*
6	7	$\frac{3}{16} \times \frac{3}{4}$
$6\frac{5}{8}$	7	$\frac{3}{16} \times \frac{3}{4}$
8	9	$\frac{1}{4} \times 1$
$8\frac{5}{8}$	9	$\frac{1}{4} \times 1$
10	$11\frac{1}{4}$	$\frac{1}{4} \times 1$
$10\frac{3}{4}$	$11\frac{1}{4}$	$\frac{1}{4} \times 1$
12	$13\frac{1}{4}$	$\frac{1}{4} \times 1$
$12\frac{3}{4}$	$13\frac{1}{4}$	$\frac{1}{4} \times 1$
14	$15\frac{1}{4}$	$\frac{1}{4} \times 1$
16	$17\frac{1}{2}$	$\frac{1}{4} \times 1$
18	$19\frac{1}{2}$	$\frac{1}{4} \times 1$
20	$21\frac{1}{2}$	$\frac{1}{4} \times 1$
24	$25\frac{3}{4}$	$\frac{1}{4} \times 1$
30	$31\frac{3}{4}$	$\frac{1}{4} \times 1$
36	38	$\frac{1}{4} \times 1$

* Spigots with the above dimensions provide approximately standard calking space in bells of Class A, Class 100 and Class 150 pipe; in bells of commonly used A.W.W.A. standard fittings, 24 in. and smaller; and for Classes A and B in 30- and 36-in. sizes. In bells of larger diameter than these, the calking space will naturally be greater, but strength for calking is adequate for all sizes of bell. As a precautionary measure, it is well to check the above dimensions against the diameter of the bell to be used in given cases.

TABLE 37

Dimensions of Extra-heavy Half-Couplings
(See Fig. 22)

Coupling Size *in.*	Over-all Dimensions	
	A *in.*	*B* *in.*
$\frac{1}{8}$*		
$\frac{1}{4}$*		
$\frac{3}{8}$*		
$\frac{1}{2}$	1.13	$\frac{27}{32}$
$\frac{3}{4}$	1.44	1
1	1.70	$1\frac{3}{32}$
$1\frac{1}{4}$	2.07	$1\frac{3}{8}$
$1\frac{1}{2}$	2.31	$1\frac{3}{8}$
2	2.81	$1\frac{1}{2}$
$2\frac{1}{2}$	3.31	$1\frac{11}{16}$
3	4.00	$1\frac{3}{4}$
$3\frac{1}{2}$	4.63	$2\frac{1}{16}$
4	5.13	$2\frac{1}{16}$

* Secure these sizes by bushing down $\frac{1}{2}$-in. coupling.

TABLE 38

Dimensions of Thredolets
(See Fig. 23)

B—in.	1 3/8	1 3/4	2 1/8	2 5/8	2 7/8	3 1/2	4 1/8	4 7/8	5 1/2	6	7 1/8	8 7/8
A—in.	7/8	7/8	1 1/8	1 1/4	1 1/4	1 1/2	1 3/4	2	2 1/8	2 1/4	2 3/8	2 1/2
	Outlet Sizes—*in.**											
Pipe Size *in.*	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	5	6
6	6×1/2	6×3/4	6×1	6×1 1/4	6×1 1/2	6×2	6×2 1/2	6×3	6×3 1/2	6×4	6×5	
8	8×1/2	8×3/4	8×1	8×1 1/4	8×1 1/2	8×2	8×2 1/2	8×3	8×3 1/2	8×4	8×5	8×6
10	10×1/2	10×3/4	10×1	10×1 1/4	10×1 1/2	10×2	10×2 1/2	10×3	10×3 1/2	10×4	10×5	10×6
12	12×1/2	12×3/4	12×1	12×1 1/4	12×1 1/2	12×2	12×2 1/2	12×3	12×3 1/2	12×4	12×5	12×6

* Outlet is tapped to standard iron pipe sizes.

when fittings are made to the American Standard shown in Fig. 29 and 30 and Table 41. It is suggested that the American Standard dimensions be used whenever possible.

Designating Fittings

Figure 29 in addition to depicting and naming various types of fittings, may be used to determine the proper sequence to be followed in specifying the size of a fitting. Each opening of the fitting is identified by a number indicating the sequence to be followed in specifying the fitting size. When reading a fitting, substitute the desired size or outside diameter in place of the numbers given. Show the desired deflection angle of elbow or lateral in place of θ in the diagram. On ordinary elbows both ends are numbered the same, because both are the same size. Thus only one diameter need be given for an elbow, together with the deflec-

TABLE 39

Plate Dimensions and Drill Sizes for Reinforced Tapped Openings
(See Fig. 24)

Size of Pipe Tap *in.*	Size of Drill for Pipe Tap *in.*	Dimensions of Plate	
		T *in.*	*D** *in.*
3/8	19/32	1/4	1 1/4
1/2	23/32	1/4	1 1/2
3/4	15/16	1/2	1 3/4
1	1 5/32	1/2	2 1/8
1 1/4	1 1/2	1/2	2 1/2
1 1/2	1 23/32	1/2	3
2	2 3/16	1/2	3 1/2
2 1/2	2 5/8	3/4	4 1/2
3	3 1/4	3/4	5
3 1/2	3 3/4	3/4	5 1/2
4	4 1/4	3/4	6

* Diameter of plate pad before curving to fit outside of pipe.

TABLE 40

Maximum Size of Threaded Openings for Given Size Pipe With Reinforcing Pads
(See Fig. 24)

Pipe Size *in.*	Max. Size Tapped Opening* *in.*
6 5/8	1 1/4
8 5/8	1 1/2
10 3/4	2
12 3/4	2 1/2
14	3
16	3 1/2
18	3 1/2
20	4

* For sizes larger than given, use the connection shown in Fig. 22, 25 or 26.

tion angle. Example: 14-in. o.d. 90-deg. ell.

Reducing crosses and elbows are always identified by first giving the size or outside diameter of the largest opening, then following with the sizes of the other openings in the numerical sequence given. Example: 24-in. o.d. × 22-in. o.d. × 8$\frac{5}{8}$-in. o.d. × 6$\frac{5}{8}$-in. o.d. cross.

Tees, laterals and double branch elbows are specified by giving the size of the largest opening of the run first, the opposite opening of the run second and the size of the outlet or branch last. Example: 16 in. o.d. × 12$\frac{3}{4}$-in. o.d. × 6$\frac{5}{8}$-in. o.d. tee.

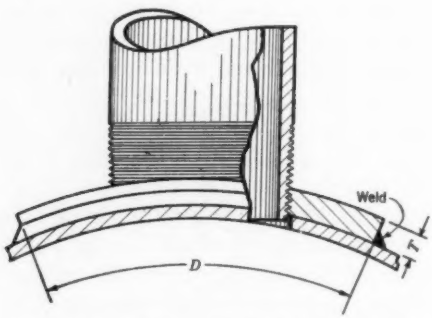

FIG. 24. Reinforcing Pad for Tapped Opening

Side outlets on fittings should have their size specified last.

When specifying side outlet tees and reducing elbows, particular care should be exercised to show whether they are right or left hand. The direction of the curvature of an elbow, or the direction of the branch of the tee (right or left) when facing the largest opening of the run, will determine whether the fitting is right or left hand.

In addition to designating the size of the fitting, a complete specification of the flanges desired, if any, should be given by the purchaser.

Reinforcement of Fittings

Tees, crosses, laterals, wyes, headers or other fittings which provide means of dividing or uniting flow in pipelines do not have as high a resistance to internal pressure as do similar sizes of straight pipe of the same wall thickness. This is because a portion of the side wall of the pipe in these fittings is removed to allow for the branching pipe. Also there are longitudinal stresses in the throat of unrestrained

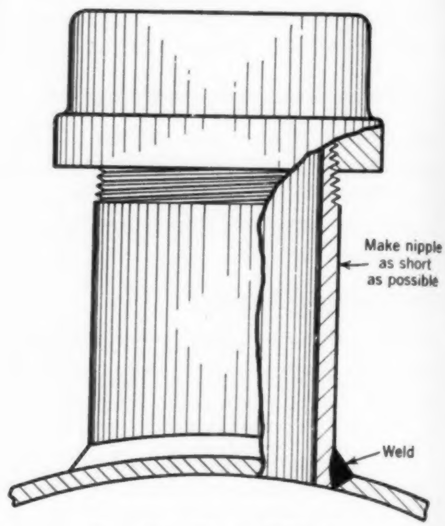

FIG. 25. Nipple With Cap

elbows, due to distortion or unbalanced hydrostatic pressure.

For ordinary water works installations carrying city water pressure, the wall thickness of the pipe commonly used is much greater than pressure conditions require. Consequently the lowered safety factor of fittings having the same wall thickness as the straight pipe still leaves adequate strength in most cases, and reinforcing is unnecessary. However, if the pipe is operating at or near maximum design pres-

sure, the strength of the fittings should be investigated and the proper reinforcement or extra wall thickness provided as may be necessary.

Fittings may be reinforced in various ways. Tie-bolts or other tension members located within the pipe barrel should be avoided if possible.

Saddle-type reinforcement is shown in Fig. 31. Here the theory is to add steel, if necessary, within prescribed

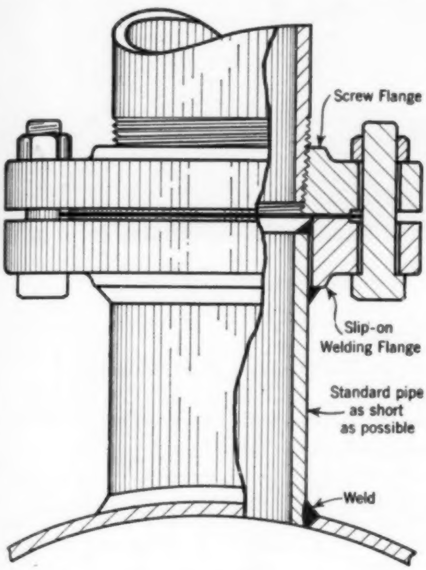

Fig. 26. Flanged Connection for Screw-Joint Pipe

distances from the opening, so that the stress or load on the steel within these bounds is not greater than it would be in an uncut pipe having a thickness equal to the theoretical minimum thickness required for pressure only.

Referring to Fig. 32, the area A represents half of the section removed by the opening for the branch. The hoop tension due to pressure within the pipe, which would be taken by this absent metal were it present, must be carried by the total of the areas X_1, X_2, X_3, X_4 and X_5. The prescribed distances along the run and along the branch are shown. Along the run, the reinforcement is confined to a distance of one diameter of the branch on each side of the branch center line. On the branch, the limit line occurs at a distance $2\frac{1}{2}$ times the thickness of the branch from the surface of the run or from the top of the saddle reinforcement. The areas of fillet welds connecting the branch and the run, or

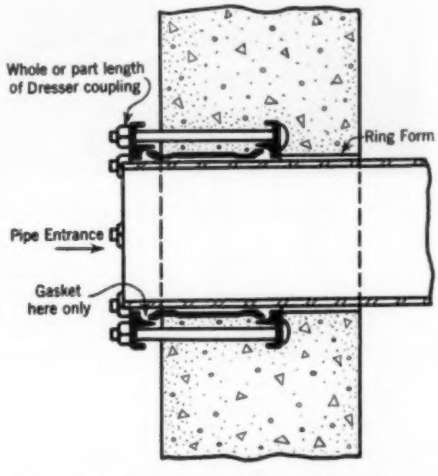

Fig. 27. Wall Connection Using Dresser Coupling

connecting any saddle used, are available for reinforcement. The design stress in the reinforcement should be not greater than the hoop stress used in the design of the pipe.

Rib-type reinforcement is shown in Fig. 33.

Girder-type reinforcement for a lateral is shown in Fig. 34.

The proper analysis and design of high-pressure fittings with rib or crotch reinforcement is an engineering problem beyond the scope of this pa-

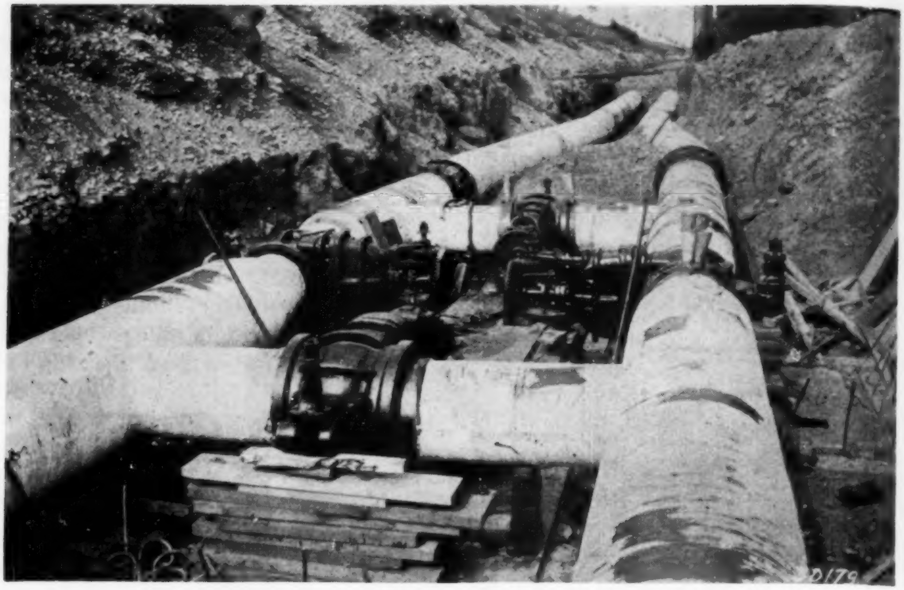

FIG. 28. Steel Pipe Specials Contain Minimum Number of Field Joints

TABLE 41

*Fitting Dimensions for Pipe With Flanges or With Ends for Field Welding**
(See Fig. 29a, 29b)

Size of Pipe o.d. *in.*	Dimensions—*in.*						
	A	*B*	*C*	*D*	*E*	*F*	*G*
6	8	11½	5	18	14½	3½	9
6⅝	8	11½	5	18	14½	3½	9
8	9	14	5½	22	17½	4½	11
8⅝	9	14	5½	22	17½	4½	11
10	11	16½	6½	25½	20½	5	12
10¾	11	16½	6½	25½	20½	5	12
12	12	19	7½	30	24½	5½	14
12¾	12	19	7½	30	24½	5½	14
14	14	21½	7½	33	27	6	16
16	15	24	8	36½	30	6½	18
18	16½	26½	8½	39	32	7	19
20	18	29	9½	43	35	8	20
22	20	31½	10	46	37½	8½	22
24	22	34	11	49½	40½	9	24
30	25	41½	15	59	49	10	30
36	28	49	18				36

* Dimensions are the same as American Standard for flanged cast-iron fittings. If elbows are to contain more miter welds than shown in Fig. 29, *A*, *B* and *C* dimensions are retained. A.W.W.A. Pipe Specifications 7A.3 and 7A.4 indicate a maximum angular change of 22½ deg. at elbow miters. This maximum has commonly been set in other fields as 30 deg. and is so shown in Fig. 29 and 30.

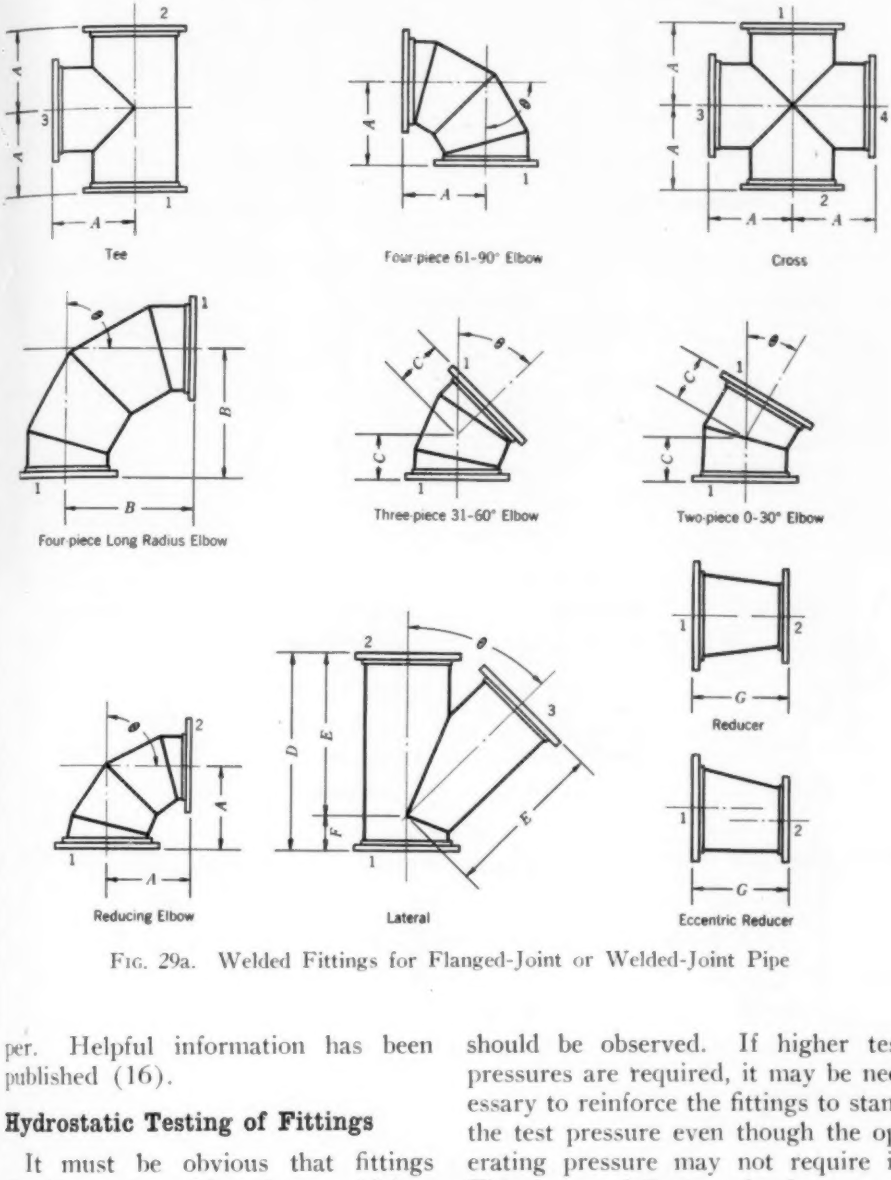

FIG. 29a. Welded Fittings for Flanged-Joint or Welded-Joint Pipe

per. Helpful information has been published (16).

Hydrostatic Testing of Fittings

It must be obvious that fittings should not be subjected to as high a mill test pressure as pipe of similar diameter and wall thickness. The A.W.W.A. specifications mention a mill test pressure of 1½ times the working pressure. This suggestion should be observed. If higher test pressures are required, it may be necessary to reinforce the fittings to stand the test pressure even though the operating pressure may not require it. This is especially true in the case of flanged fittings which would be anchored in actual service, but which, if unrestrained, are subjected to tremendous unbalanced forces when shop-tested at high pressure.

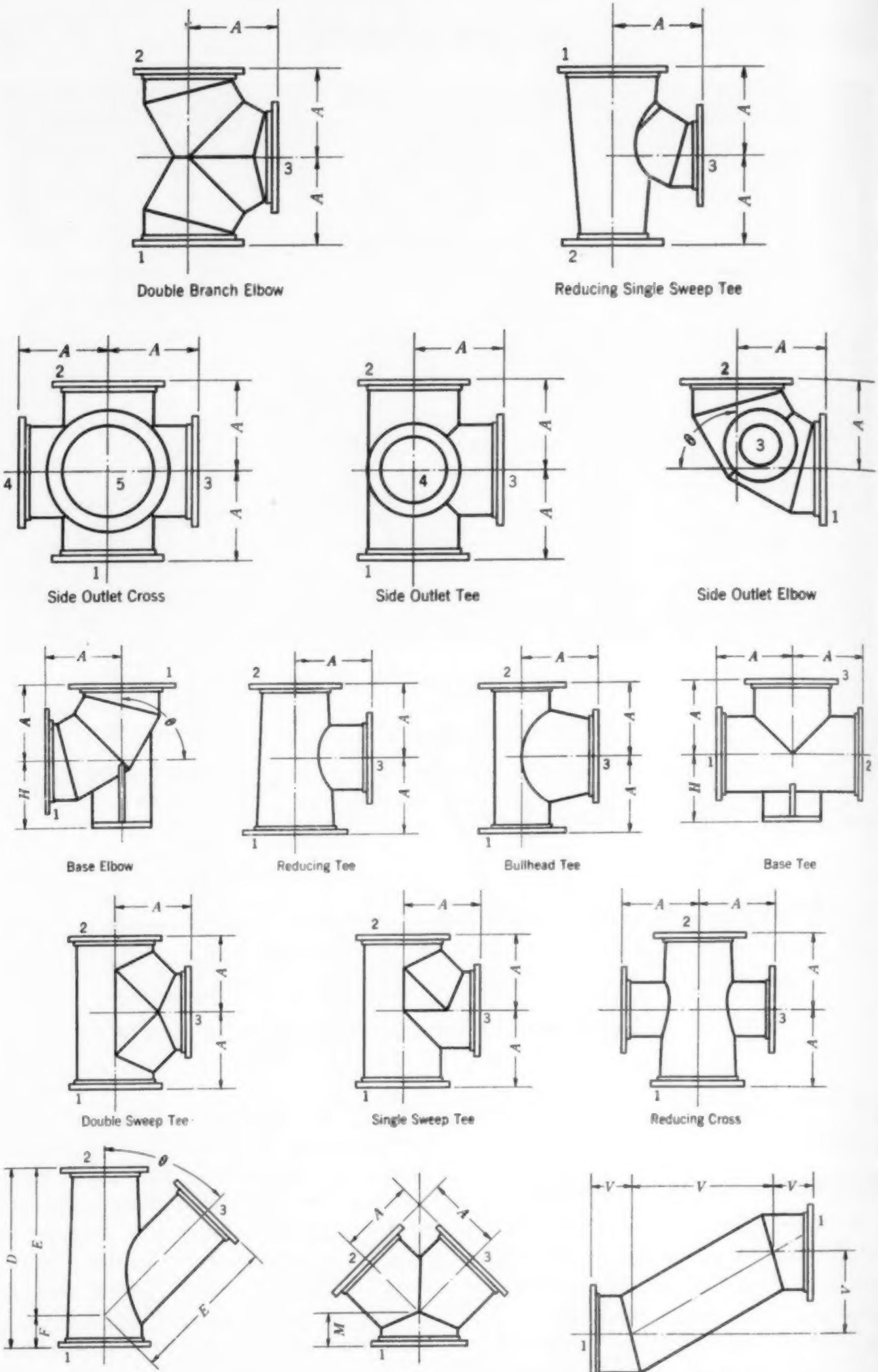

FIG. 29b. Welded Fittings for Flanged-Joint or Welded-Joint Pipe

‡ V varies.

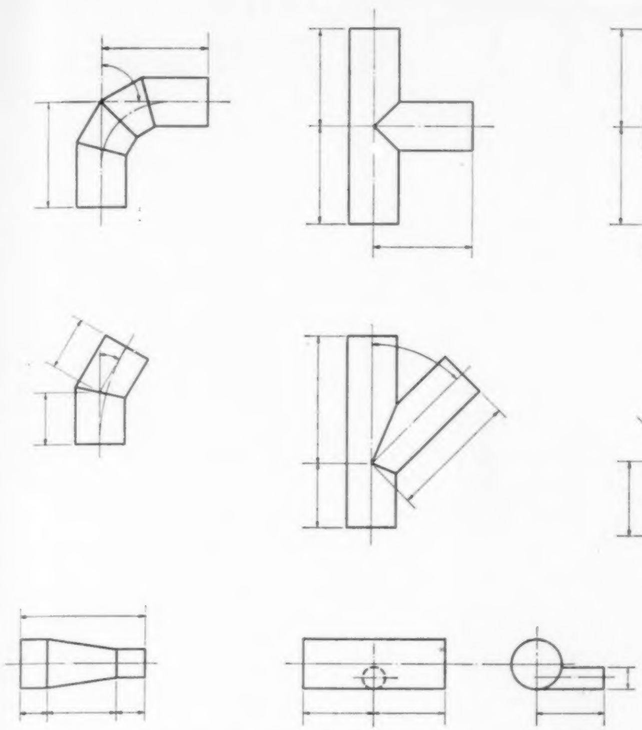

FIG. 30. Typical Fittings With Ends for Dresser Couplings
(See Text for Dimensions)

TABLE 42

Data for Calculating Reaction at Pipe Elbows for Various Pipe Diameters and Deflection Angles
(See Fig. 35)

Diam. of Pipe D *in.*	D^2 *sq.in.*	Deflection Angle d *deg.*	Coefficient C
6	36	2	0.028
8	64	4	0.055
10	100	6	0.082
12	144	8	0.110
14	196	10	0.137
16	256	15	0.206
18	324	20	0.273
20	400	30	0.402
22	484	45	0.602
24	576	60	0.785
30	900	75	0.957
36	1,296	90	1.111

TABLE 43

Hydraulic Load on Dead Ends and Flange Cover Plates per 100 psi. of Internal Pressure

Pipe Diam. *in.*	Load* *lb.*	Pipe Diam. *in.*	Load* *lb.*
6	2,800	18	25,500
8	5,000	20	31,400
10	7,900	24	45,200
12	11,300	30	70,700
14	15,400	36	101,800
16	20,100		

* The tabulated load, or disjointing force, equals 100 times the nominal cross-section area of the pipe in square inches. For pressures other than 100 psi., the load will be in direct proportion. Thus, for 16-in. pipe, the load at 50 psi. equals 0.5 (20,100), or 10,050 lb.; the load at 150 psi. equals 1.5 (20,100), or 30,150 lb.

Reaction at Pipe Elbows and Dead Ends

An unrestrained elbow in a pipeline under internal pressure causes an unbalanced force which tends to disjoint the elbow and adjacent pipe sections. A thrust block must be placed at the back of the elbow to counteract this force, or, alternatively, the joints at the elbow, and perhaps in the adjacent pipe, must be designed to take tension. (See Dresser coupling harness.)

FIG. 31. Saddle-Type Reinforcing

The thrusting forces and their reaction are shown in Fig. 35. To find the magnitude of the reaction, let T be the thrust (lb.) in the direction of the pipe axis, D the diameter of pipe (in.), P the internal pressure (psi.), d the angle of deflection (deg.) and R the resultant reaction (lb.). Then

$$R = 2T \sin \frac{d}{2}$$
$$T = 0.7854\ D^2P$$
$$R = 1.5708\ D^2P \sin \frac{d}{2}$$
$$R = CD^2P.$$

D^2 and coefficient C may be found in Table 42.

TABLE 44

Theoretical Frictional Resistance to Endwise Movement of Pipe Embedded in Earth

Pipe Size *in.*	Resistance per Linear Foot of Pipe for Depth of Cover as Shown		
	3 ft. *lb.*	4 ft. *lb.*	5 ft. *lb.*
6	120	160	210
8	150	200	270
10	180	250	320
12	210	300	370
14	240	340	420
16	270	380	480
18	300	420	530
20	320	450	570
24	390	510	660
30	480	650	810
36	570	750	930

Example: Find the reaction at a 30-in. 90-deg. ell under 150 psi. pressure.

$$\begin{aligned} R &= CD^2P \\ &= 1.111\ (900)\ 150 \\ &= 150{,}000 \text{ lb.} \\ &= 75 \text{ tons.} \end{aligned}$$

The hydraulic load on dead ends and flange cover plates is easily obtained by using the data in Table 43.

TABLE 45

Dimensions and Bearing Loads for Anchor Rings in Concrete
(See Fig. 44)

Pipe o.d. *in.*	Ring o.d. *in.*	Ring Width A *in.*	Permissible Load on Ring *lb.*
$6\frac{5}{8}$	$8\frac{5}{8}$	1	13,000
$8\frac{5}{8}$	$10\frac{5}{8}$	1	16,000
$10\frac{3}{4}$	$13\frac{3}{4}$	$1\frac{1}{2}$	30,000
$12\frac{3}{4}$	$15\frac{3}{4}$	$1\frac{1}{2}$	35,000
14	18	2	50,000
16	20	2	55,000
18	22	2	63,000
20	26	3	110,000
24	30	3	128,000
30	38	4	215,000
36	44	4	250,000

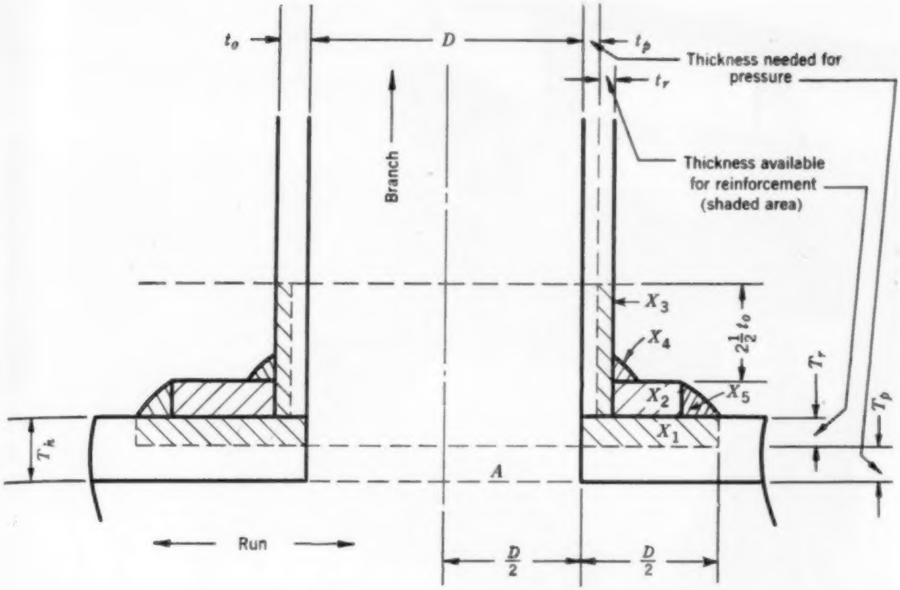

FIG. 32. Reinforcement of Openings in Welded Pipe

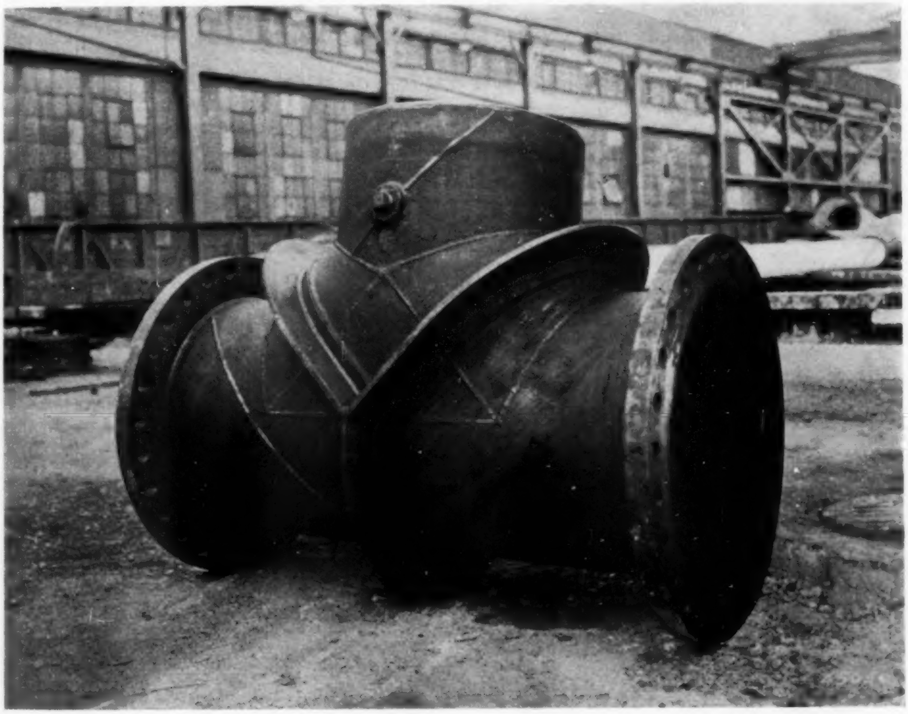

FIG. 33. Rib-Type Reinforcing

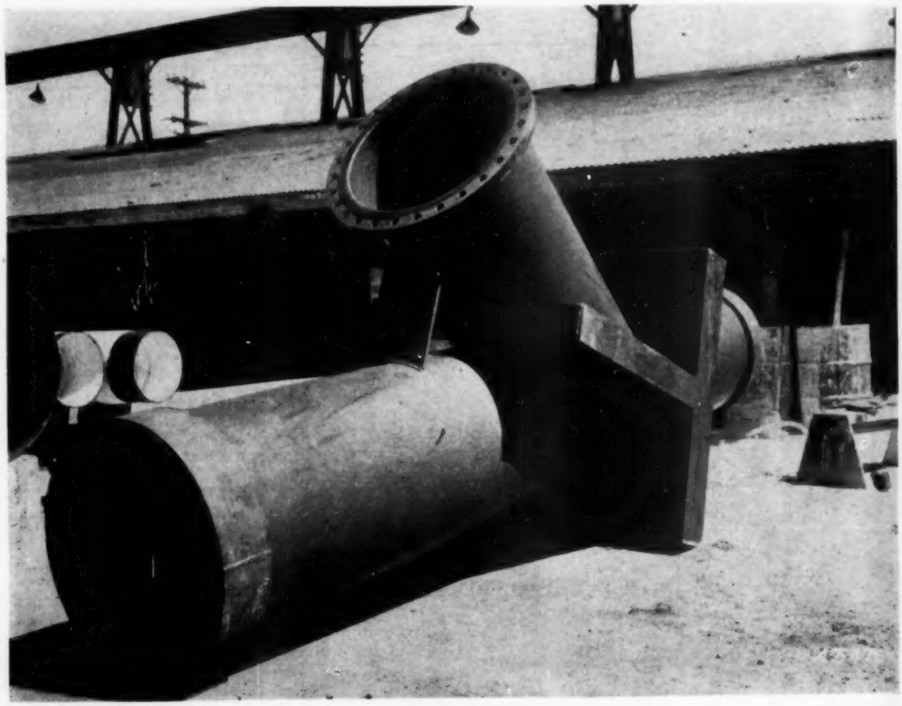

FIG. 34. Girder-Type Reinforcing

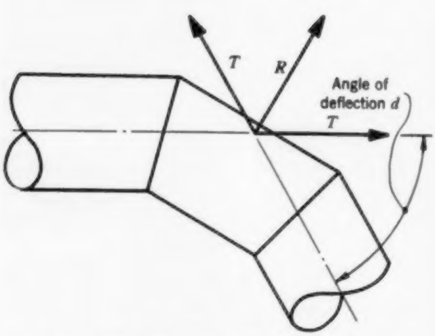

FIG. 35. Reaction at Pipe Elbow

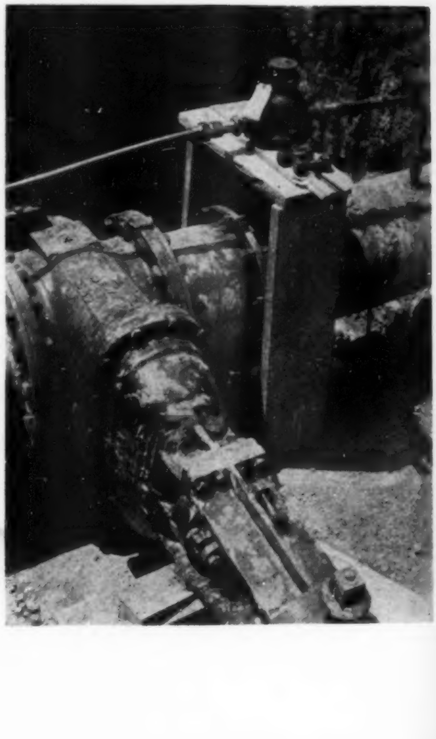

FIG. 36. Flanged Valve With Adjacent Dresser Coupling (Meter Is for Leakage Test)

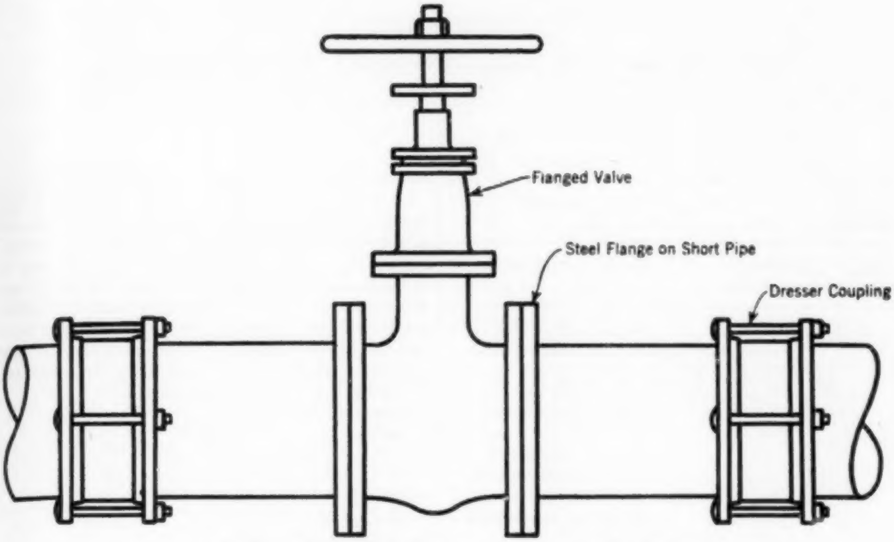

FIG. 37. Flanged Valve With Dresser Couplings

Friction or Resistance Between Soil and Pipe

If an unrestrained elbow is tied to buried pipe so that a tension is placed on the pipe to prevent elbow movement, it may be necessary to determine the length of the pipe on which the earth friction will overcome the disjointing force. Several assumptions must be made which may be open to criticism. Those here used are con-

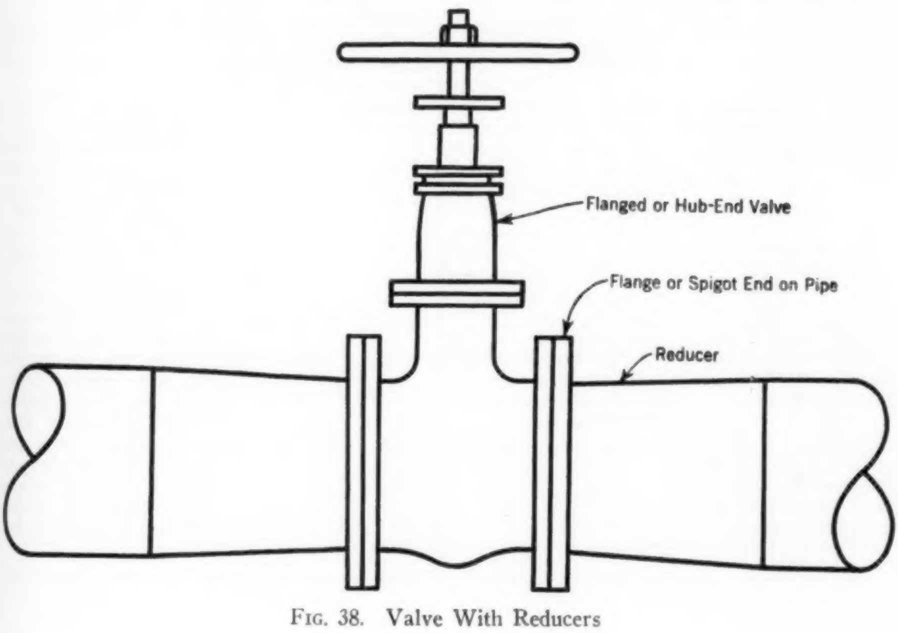

FIG. 38. Valve With Reducers

TABLE 46

Information Necessary to Supplement A.W.W.A. Steel Pipe Specifications

A.W.W.A. 7A.3 Sec. 3-1.2	A.W.W.A. 7A.4 Sec. 4-1.2	A.W.W.A. 7A.3 Sec. 3-1.2	A.W.W.A. 7A.4 Sec. 4-1.2
1.2.1. Nominal inside diameter of pipe.	1.2.1. Outside diameter.	1.2.8. Detailed description and drawings of all special sections, indicating, for each component part, the dimensions, the standard specifications number and the grade of material required, the type of ends, and the required hydrostatic test pressure.	1.2.9. Detailed description and drawings of all special sections and special fittings, indicating, for each component part, the dimensions, the grade of material, the type of ends and the hydrostatic test pressure.
1.2.2. Thickness of steel plate material.	1.2.2. Wall thickness.	1.2.9. Detailed description and drawings of all adaptors, indicating, for each component part, the dimensions, the standard specifications number and the grade of material required.	
	1.2.3. Nominal weight per foot (uncoated).	1.2.10. Shop drawings to be furnished by the contractor for all pipe and special sections under these specifications.	
	1.2.4. When a particular class of pipe as listed in Table 1 in Sec. 4-2.1 is required, it shall be so stated; otherwise all classes shall be considered equal alternates.	1.2.11. Stress relieving of special pipe sections if specified (see Appendix).	
1.2.6. Detailed description of the type of pipe ends with all drawings necessary to show shape, width, thickness, beveling or other details. Types of pipe ends are indicated in Sec. 3-2.4 of these specifications.	1.2.5. Detailed description of the type of pipe ends with all drawings necessary to show shape, width, thickness, beveling or other details. Types of pipe ends are indicated in Sec. 4-2.7 of these specifications.		1.2.10. Kind of corrosion protection and whether it is to be applied in the field or at the mill (complete details of the coating to be applied, whether the pipe is to be completely coated from end to end, or if a certain specified distance at the end shall be left bare, or be oil-varnished or painted with designated material, either for field-welding or to accommodate mechanical-type couplings, or to provide for other types of field joints).
1.2.3. Laying length of pipe sections.	1.2.6. Lengths (random, double-random or specified).		
1.2.5. The number of longitudinal and girth seams for each pipe section.	1.2.7. The maximum number of longitudinal and girth seams permitted in each *fabricated* pipe section or the maximum number of lengths of *mill* pipe joined, in accordance with Sec. A4-2 in the Appendix to these specifications.		
1.2.4. Working water pressure for each plate thickness of pipe.	1.2.8. The maximum working water pressure, including water hammer allowance.		
1.2.7. Standard specifications number and the grade of steel plate material required.			

TABLE 47

Information Necessary to Supplement A.W.W.A. Coating Specifications

A.W.W.A. 7A.5 Sec. 5-1.3(c)	A.W.W.A. 7A.6 Sec. 6-1.3(c)
1. *Project:* Diameter, length, and location of pipe line, etc.	1. *Project:* Diameter, length, and location of pipe line, etc.
2. *Soil:* Character of soil to be encountered as determined by tests and/or inspection; depth of cover, etc.	2. *Soil:* Character of soil to be encountered as determined by tests and/or inspection; depth of cover, etc.
3. *Temperatures:* Range of atmospheric temperatures to which the pipe may be subjected during, or subsequent to, installation.	3. *Temperatures:* Range of atmospheric temperatures to which the pipe may be subjected during, or subsequent to, installation.
4. *Exterior Protection—Underground:* Length of line to be protected for underground service.	4. *Exterior Protection—Underground:* Length of line to be protected for underground service.
5. *Exterior Protection—Aboveground:* Length of line to be erected aboveground for atmospheric service.	5. *Exterior Protection—Aboveground:* Length of line to be erected aboveground for atmospheric service.
6. *Contractor's Samples:* Requests for contractor's samples in accordance with Sec. 5-2.4 of these specifications.	
7. Additional exterior pipe protection selected from the Appendix of these specifications (7A.5).	
8. *Materials:* When "Corrosion Protection" outlined here is to be done by force account or by separate contract, specify: etc.	6. *Materials:* When "Corrosion Protection" outlined here is to be done by force account or by separate contract, specify: etc.

servative, because at least two checks are available from field measurements.

In one case, the frictional resistance of 6-in. pipe in a 5-ft. trench was measursed as 500 lb. per linear foot of pipe. The pipe had no projections. In another case the measured resistance of an empty 60-in. wrapped steel pipe with a 3-ft. loose cover *for one-third of its length* was 700 lb. per linear foot. These figures compare with the calculated resistances of *200* and *250* lb. per linear foot of pipe respectively, using the method followed in developing the frictional resistances shown in Table 44. The theoretical resistances offer a

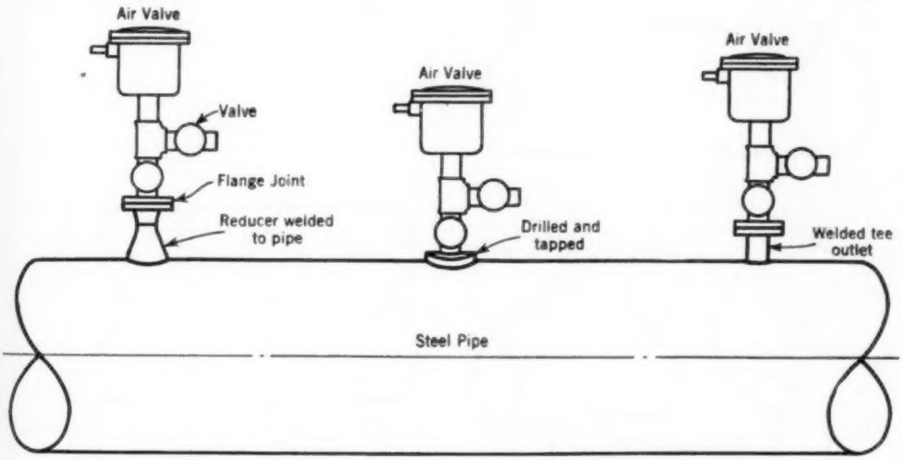

FIG. 39. Alternative Connections for Air Valves

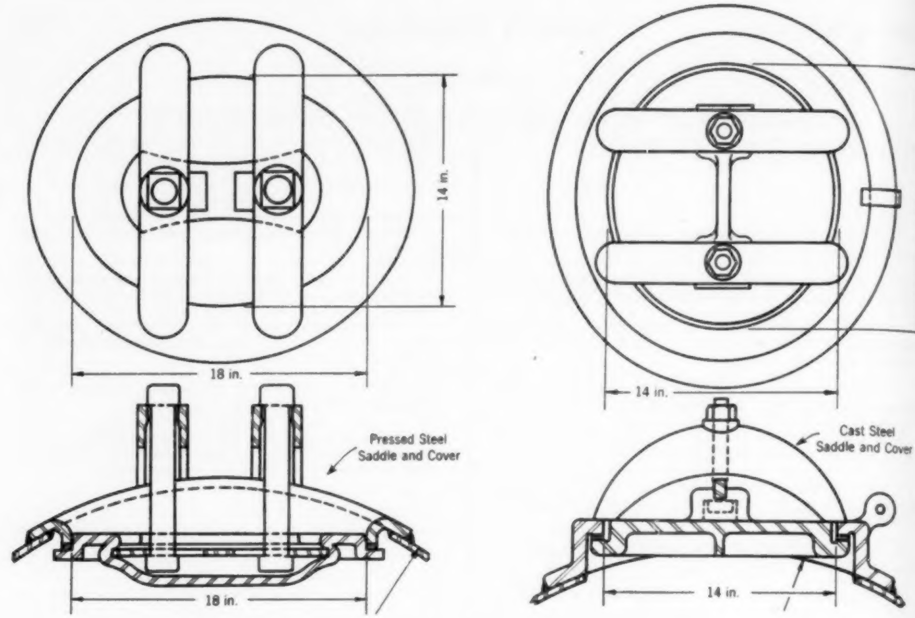

FIG. 40. Detail of Manhole (Self-sealing Type)

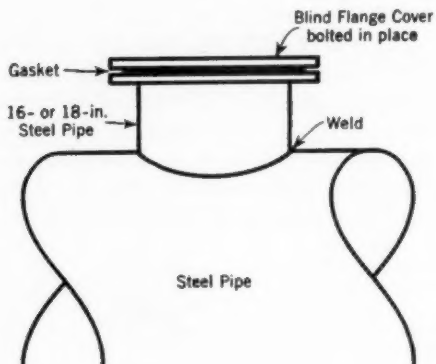

FIG. 41. Detail of Entry-Port (Tee-Connection Type)

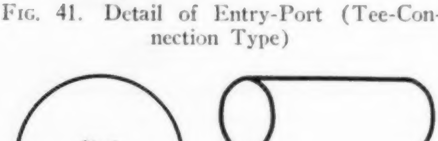

FIG. 42. Blow-off (Tee-Connection Type)

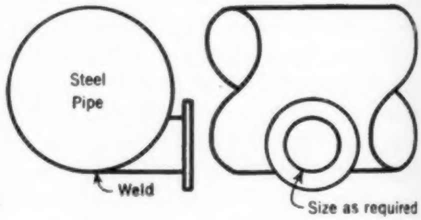

FIG. 43. Blow-off (Tangential Type)

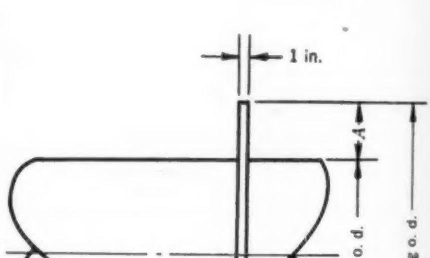

FIG. 44. Anchor Ring

safety factor of about 2.5 against the measured ultimate resistances probably because no account is taken of side grip.

The figures in Table 44 were calculated on the theory that the frictional resistance is 30 per cent of the combined weight of pipe and contents and the earth load on the pipe. In detail, the data are: depth of cover, as given; weight of pipe, taken as the minimum weight of mill pipe listed in A.W.W.A. Specification 7A.4 (2) and (for ¼-in. wall pipe) in Specification 7A.3 (1). Weight of contents, water at 62.4 lb. per cubic foot; earth load on pipe, from ASA A21.1–1939 (7) for width of ditch 2 ft. greater than the pipe diameter and for field conditions *A, B, C, E* and *F;* friction factor, 0.3.

Connections to Valves

Valves may be connected with pipelines in various ways. Figure 36 illustrates the use of Dresser couplings with a flanged valve. The meter supported above the coupling was used in the leakage test. Figures 37 and 38 illustrate commonly used methods of joining flanged valves to pipe.

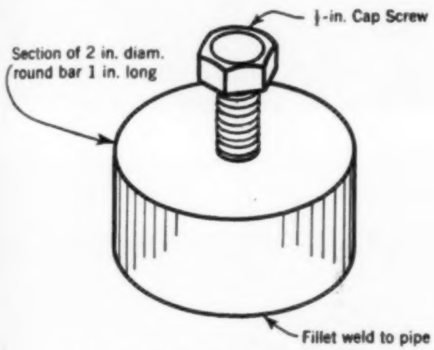

FIG. 45. Electrolysis Connection

By removing the center stops from the middle rings, Dresser couplings may be moved axially along the pipe to uncover the joint between pipe sections. This arrangement makes it comparatively simple to insert or remove valves in pipelines. At the same time, the Dresser couplings prevent thrust or tension in the valve itself due to line stresses. Figure 39 shows three simple means of connecting air valves to pipe.

TABLE 48

Dimensions of Coupling Coating Pans
(See Fig. 51)

Size of Pipe o.d. *in.*	Dimensions—*in.*		
	A	*B*	*C*
6⅝	11½	7	14
8⅝	13½	9	14
10¾	15¾	11⅛	14
12¾	17¾	13⅛	14
14	19	14⅜	14
16	21¼	16⅜	14
18	23¼	18⅜	14
20	25¼	20⅜	14
22	27½	22⅜	14
24	30	24⅜	14
30	35	30⅜	17
36	42	36⅜	17

Miscellaneous Appurtenances

Manholes or Entry Ports

Manholes, frequently used, may be of the self-sealing type shown in Fig. 40. Entry ports, infrequently used, may be of the ordinary tee-connection type shown in Fig. 41. The tee connection will usually be more economical in first cost.

Blow-offs

Blow-offs may be of the tee-connection type shown in Fig. 42 or the tangential type shown in Fig. 43. Cir-

FIG. 46. Inside of Coupling Coating Pan

FIG. 47. Outside of Coupling Coating Pan

FIG. 48. Attaching Coating Pan

FIG. 49. Coating Pan Attached

cumstances of installation and operation will dictate the type and size to be used.

Anchor Rings

Anchor rings for use in concrete anchor blocks or concrete walls are shown in Fig. 44. Corresponding dimensions and thrust or pull loads are given in Table 45. Rings are proportioned to accept dead-end pull or thrust imposed by 250 psi. internal pressure, with approximately 500 psi. bearing on concrete. The recommended fillet welds offer such a high safety factor against shear that half the amount can be used, with the weld intermittent on both sides.

Electrolysis Connections

A simple, inexpensive and satisfactory electrolysis connection is shown in Fig. 45. This provides a good electrical connection, using a device which does not project beyond the pipe wall enough to interfere with loading and shipping. Angles welded to pipe have also been used but are not recommended.

FIG. 50. Pouring the Coating

Pipe Specifications

The A.W.W.A. Standard Pipe Specifications are virtually self-contained. However, certain supplementary information is required by the contractor and the pipe manufacturer. The data which the engineer should supply are listed for steel water pipe in Table 46 and for protective coating in Table 47.

Protective Coating for Steel Water Pipe

The several types of protective coatings provided for in the A.W.W.A. Specifications are given below. The summary will aid the engineer in se-

lecting the coating he deems best to protect the pipe under the conditions encountered.

The practice of protecting pipe varies. For sizes up to and including 36 in., more commonly than not, the pipe is wrapped with asbestos felt. The coating applied to all pipe in this size range is usually that labeled Type I in the summary of A.W.W.A. Specifications 7A.6 (11), rather than Type I or Type III of 7A.5 (10). The practice is recommended in this size range because of the extra protection afforded by the wrapping.

Type II. *Standard Underground Protection—With Sand Shield.* This selection is based on a sand shield as defined in Sec. A5–1.2(a). The coating and lining are the same as Type I above.

Type III. *Special Undergound Protection—With Felt Wrapper.* This selection is based on Sec. A5–1.3(a) for extreme soil conditions. It consists of:

A. Coal-tar primer for interior and exterior surfaces
B. Coal-tar enamel for interior and exterior surfaces
C. Coal-tar enamel for bonding felt to the underlying coat of enamel on exterior surfaces

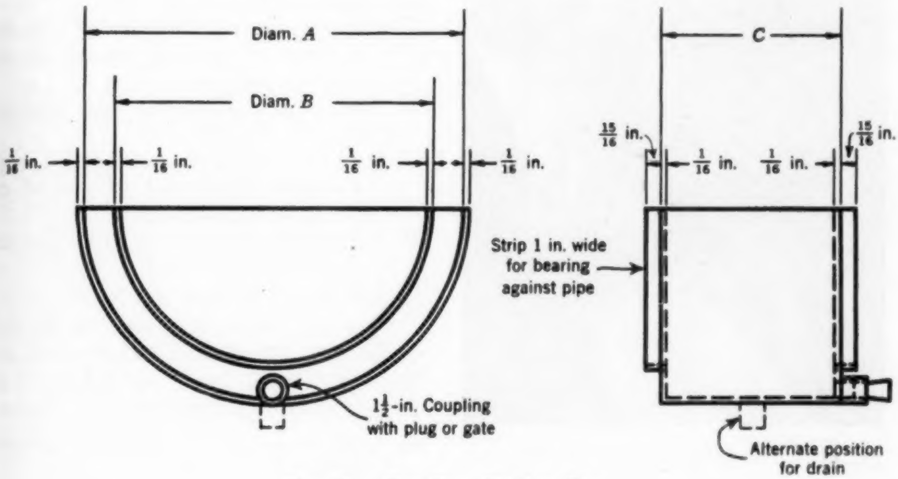

Fig. 51. Coupling Coating Pan

D. Coal-tar saturated felt bonded to exterior surfaces to mitigate soil stress effect.

A summary is given below of the several types of coatings included in the A.W.W.A. Standard Specifications 7A.5 (10), applying to steel water pipe of 30-in. diameter and over:

Type I. *Standard Underground Protection—With Graded Backfill.* This selection is based on graded backfill as defined in Sec. 5–4.5(c). It consists of:

A. Coal-tar primer for interior and exterior surfaces
B. Coal-tar enamel for interior and exterior surfaces
C. Whitewash.

Type IV. *Special Underground Protection—With Gunite Shield.* This selection is based on Sec. A5–1.4(a) for exceedingly large and heavy pipe in very extreme cases. It consists of:

A. Coal-tar primer for interior and exterior surfaces
B. Coal-tar enamel for interior and exterior surfaces
C. Reinforced gunite shield for severe external conditions

D. Concrete sealing compound (see Sec. A5–2.5)
E. Whitewash over concrete curing or sealing compound.

Type V. *Special Protection for Exposed Pipe—Syphons, Bridge Pipe, etc.* This selection is based on Sec. 5–5.1 of the Standard Specifications and comprises:

A. Coal-tar primer for interior surfaces only
B. Coal-tar enamel for interior surfaces only
C. Red-lead primer for exterior surfaces only

Fig. 52. Protecting a Field-welded Joint

D. White-enamel and/or aluminum finishing coat for exterior surfaces only

The following summarizes the several types of coatings included in the A.W.W.A. Standard Specifications 7A.6 (11), applying to steel water pipe of sizes below 30-in. diameter:

Type I. *Standard Underground Protection—With Graded Backfill.* This selection is based on graded backfill as defined in Sec. 6–5.6(c). It consists of:

A. Coal-tar primer for interior and exterior surfaces
B. Coal-tar enamel for interior and exterior surfaces
C. Coal-tar saturated felt
D. Whitewash or kraft paper.

Type II. *Standard Underground Protection—With Sand Shield.* This selection is based on a sand shield as defined in Sec. A6–1.2(a). The coating and lining are the same as Type I above.

Type III. *Special Undergound Protection for Extraordinary Soil Conditions,* as defined in Sec. A6–1.3(a). It consists of:

A. Coal-tar primer for interior and exterior surfaces
B. Coal-tar enamel for interior and exterior surfaces
C. Coal-tar saturated felt bonded with the underlying coat of enamel on the exterior surfaces
D. Additional application of coal-tar enamel over the felt
E. Coal-tar saturated felt bonded with the underlying coat of enamel on the exterior surfaces
F. Additional application of coal-tar enamel over the felt
G. Whitewash or kraft paper.

Type IV. *Special Protection for Exposed Pipe—Syphons, Bridge Pipe, etc.* This selection is based on Sec. 6–5.1 of the Standard Specifications and includes:

A. Coal-tar primer for interior surfaces only
B. Coal-tar enamel for interior surfaces only
C. Red-lead primer for exterior surfaces only
D. White-enamel and/or aluminum finishing coat for exterior surfaces only.

Field Joint Protection

When steel water pipe is coated at the mill or at a railhead coating plant, a short distance is left bare on each end of every pipe section. After field assembly this uncoated portion of the pipe as well as the joint must be field coated.

In the case of Dresser couplings, the most satisfactory method is to use a coupling coating pan. The coating pan is illustrated in Fig. 46 and 47, and the steps in its use are shown in Fig. 48-50. A detail of the coupling coating pan is given in Fig. 51 with corresponding dimensions in Table 48.

When steel pipe is supplied with felt wrapping, it is sometimes desirable to place strips of felt adjacent to the couplings after they are coated. This is done by loosely holding the loops of felt against the bottom of the pipe, pouring hot coating on each side, gradually bringing the felt into contact with the pipe at all points, and sealing down with hot coating.

The method of protecting a field-welded joint is shown in Fig. 52.

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Water Legislation in Michigan

By John M. Hepler

A paper presented on Sept. 20, 1947, at the Michigan Section Meeting, Bay City, Mich., by John M. Hepler, Director, Bur. of Eng., Michigan Dept. of Health, Lansing, Mich.

"WATER, water everywhere, nor any drop to drink," may be a correct statement of fact in some areas of the United States, but it certainly cannot be said that the water everywhere in Michigan has not been made available to drink. The people can indeed voice no criticism of the State for not making it possible to supply drinking water to its municipalities. In fact, it would appear that making water available on a utility basis was one of the early considerations of the Michigan State Legislature.

Early Legislation

The matter was being considered as far back as 1869, when the legislature passed an act (Act 113, P.A. 1869) "to authorize the formation of companies for the introduction of water in the towns, cities and villages in the State of Michigan." That incorporated cities and villages had some power to provide water prior to this time is indicated by the language of Sec. 1 of the act, which reads:

Whenever the common council of any city or incorporated village, or the municipal authorities of any town in this State shall, by resolution, declare that it is expedient to have constructed works for the purpose of supplying such city, village or town and the inhabitants thereof with water, but that it is inexpedient for such city, town or village under the power granted in its charter, to build such works, it shall be lawful for any number of persons, not less than five, to organize a company for the construction of such water works, or for any company previously organized, to construct such water works under the provisions of this act. . . . After the expiration of 25 years from the time of the organization of such company, the common council of the city, town or village for which the said company may have erected its works, shall have the right and privilege of purchasing from such company all its buildings, reservoirs, fixtures, apparatus and property . . . with all its corporate rights and privileges, at such price as may be agreed upon. . . .

The impression that this act might be held to limit the life of water companies to 25 years was later corrected by Act 82, P.A. 1901, which provided for "renewing the incorporation of companies organized for the purpose of the introduction of water into towns, cities and villages." When the life of a water company was about to terminate by limitation of law, the company was empowered "to direct the continuance of its corporate existence for such further term, not exceeding 30 years, as may be expressed in a resolution passed for that purpose." This provision was apparently intended to insure the continua-

tion of the utility in the event that the municipality did not choose to acquire the property.

The existence of objections to placing the water utility in the hands of a private corporation is evident from the passing of Act 5, P.A. 1870, which authorized the municipal financing of water supplies. Section 1 of the act states:

> . . . that it shall be lawful for any city or incorporated village in this State to borrow any sum of money to be used exclusively for the purpose of purchasing grounds, rights, privileges, materials, and in making improvements connected with, and for the sole purpose of, supplying such city or village, and the inhabitants thereof, with water; provided, that the total sum borrowed and raised by tax by any such municipality the first year shall not exceed 10 per cent of the assessed valuation of such municipality, as contained in the last preceding assessment roll of the same; and provided, that no more than 5 per cent shall be borrowed during any one year thereafter, and that the rate of interest shall not exceed 10 per cent upon any indebtedness contracted under the provision of this act.

The act specifically stated that it should not be construed to affect the special provisions in the charter of any city or village already authorizing a municipally controlled water supply. It also provided that "any city or village which may have availed itself of existing provisions of law to become a stockholder in any water company, may, by an arrangement with the company in which it owns stock, and with other stockholders thereof, by purchase, acquire the entire rights of such water company. . . ."

Apparently the acts of 1869 and 1870 did not provide the necessary machinery for the development of water supplies as time advanced. In 1883 another act was passed "to authorize the formation of corporations for the purpose of excavating, constructing and maintaining water courses with water power appurtenant thereto, for accumulating, storing, conducting, selling, furnishing and supplying upon an agreed rental, water and water power for mining, milling, manufacturing, domestic, municipal and agricultural uses" (Act 39, P.A. 1883). It provided that five or more persons could form a corporation to acquire or lease the lands or water power necessary for the purposes set forth in the act. It was undoubtedly meant to deal with a specific condition in the Upper Peninsula, because the corporate powers included the right to examine and survey for the proposed improvements "of dams, canals or digging and deepening of channels;" to purchase, and, by voluntary grants and donations, to receive and use the lands and real estate necessary for the construction, maintenance, and operation of dry docks, canals and other works proposed in the approved plans; to divert into any canal excavated or constructed under the provisions of the act, water from Lake Superior or St. Mary's River; to flood the land belonging to the company, subject to the consent of the county board of supervisors; and to erect docks in Lake Superior or St. Mary's River. This act is public to the extent that it authorizes other companies to organize under it, but it is local, since it restricts the diversion of water to Lake Superior and the St. Mary's River (*Attorney General* v. *Arnott,* 145 Michigan 416, 420; 108 N.W. 646).

Municipal Corporations

The act of 1883 appears to have met all of the contemporary requirements

until 1895, when the previous system of incorporating cities and villages by local acts of the legislature was changed. General enabling legislation providing for the incorporation of villages and fourth class cities was adopted. Act 3, P.A. 1895, permits any part of a township not included in an incorporated village, and containing an area of at least ¾ square mile with a minimum resident population of 250, to be incorporated as a village. The act then proceeds to define the nature and the powers of its governing body. Chapter 9 refers to water works:

> Any village having a resident population of 300 or over shall have authority to purchase or construct and maintain water works for the introduction of water into the village and supplying the village and inhabitants thereof with pure and wholesome water, for the extinguishment of fires, the ordinary and extraordinary uses of the inhabitants thereof and for such other purposes as the council may prescribe; and may also construct and maintain a filtration plant for the purification of the water supply of the village. . . . The village may acquire, purchase, erect and maintain such reservoirs, canals, aqueducts, sluices, buildings, engines, water wheels, pumps, hydraulic machines, distributing pipes and other apparatus, appurtenances and machinery, and may acquire, purchase, appropriate and own such ground, real estate, rights and privileges as may be necessary and proper for the securing, constructing, rebuilding, repairing, extending and maintenance of such water works or filtration plants.

This section illustrates the regard paid to water supplies at the time. The utility was further protected by a provision that the connecting or supplying pipes leading from buildings or yards to the distributing pipes should be inserted and kept in repair at the expense of the owner or occupant of the building and should not be connected with the main pipe until a permit was obtained from the council. The council was empowered to establish a scale of water rates appropriate to different types of buildings classified according to dimension, value, exposure to fire, ordinary or extraordinary uses, number of families or occupants, and amount of water consumed. To insure the obtaining of a water supply, the act provides that water works may be purchased or constructed beyond the corporate limits of the village. It also provides, in view of the previous authority for the creation of water companies, that the council can contract, annually or for a maximum period of ten years, with any person or duly authorized corporation to supply the inhabitants with water.

Act 215, P.A. 1895, provided in a similar manner for the incorporation of cities of the fourth class and prescribed the nature and the duties of their governing bodies. Cities of the fourth class were defined as those containing a population of from 3,000 to 10,000. A chapter in the act grants permission to the city to purchase, construct, maintain and extend water works. It is interesting to note that although villages were empowered to borrow up to 10 per cent of the assessed valuation of their property for this purpose, fourth class cities were limited to 5 per cent.

For a period of fourteen years no further water legislation was passed, except for a section of the constitution of 1908, which states that:

> Subject to the provisions of this constitution, any city or village may acquire, own and operate, either within or without its corporate limits, public utilities for supplying water, light, heat, power and

transportation to the municipality and the inhabitants thereof; and may also sell and deliver water, heat, power and light without its corporate limits to an amount not to exceed 25 per cent of that furnished by it within the corporate limits. . . .

This 25 per cent limitation on the sale of water outside the corporate limits was changed by an amendment ratified by the people in November 1944. Although the 25 per cent restriction on the sale of heat, power and light was retained, water may now be delivered outside of the corporate limits "in such amount as may be determined by the legislative body of the city or village."

In 1909 provision was made for the incorporation of cities and the revising and amending of their charters to create what are known as "home rule cities." Act 279, P.A. 1909, permitted the city to include in its charter the right to "acquire by purchase or condemnation proceedings any land within or without its corporate limits necessary for disposing of sewage or for obtaining or protecting a water supply for the city and the inhabitants thereof, and [to] acquire by purchase or condemnation proceedings, when authorized by the electors, . . . any public utility and any water power and water rights for the use of such city within the corporate limits. . . ."

Public Health Law

In the same year the first legislation to control the safety of drinking water was passed. Act 28, P.A. 1909, authorized the State Board of Health to exercise "supervisory and visitory power and control over all corporations other than municipal, partnerships and individuals engaged in furnishing water to the public for household or drinking purposes and over the plants and systems owned or operated by such companies or individuals." The board was given authority to make and enforce the necessary rules and regulations "governing and providing a method of conducting and operating the entire, or any part of the, system of water works, including the filtration plants as are operated by said corporations other than municipal." The act made it obligatory to file plans and specifications with the board and to obtain its approval within 60 days after commencing to operate or within 60 days after alterations, additions or improvements were made. A penalty was imposed for failure to submit plans. The filing of operating reports was also required. This act contained the essential supervisory powers under which the Michigan Dept. of Health still operates. Act 98, P.A. 1913, superseded the act of 1909, but retained much of the original wording. In 1913 sewerage systems and municapally owned water works, previously exempted from control, were brought under the supervision of the Board of Health. The Act of 1913 has been amended on six occasions. These amendments include requirements for the approval of plans and the issuance of construction permits before the work begins, for the classification of water treatment plants and for the certification of operators. Basically, the health department has been striving to achieve and maintain safe water supplies for public consumption since 1909.

Bond Validation

About this time the legality of the bonds which had been issued to acquire water systems was questioned. As a result, Act 3, P.A. 1911, was passed and given immediate effect for

the protection of the public health. The act declares that:

Whenever the common council of any city shall have heretofore submitted to the electors thereof the question of issuing bonds for the extension of its water mains or for securing a site and establishing and constructing a rapid sand filtration plant or other filtration plant, such bonds to run for a period of 20 years with interest not to exceed 5 per cent per annum . . . and a majority of the legal electors voting thereon has voted in favor of issuing said bonds, . . . such proceedings shall be held valid and authority for the legislative body of any such city to execute, or cause to be executed and sold, the bonds voted as aforesaid, notwithstanding the charter of such city provided that before action of the common council and the submission of the question of issuing such bonds to the electors, the board of public works of such city, deeming the work called for by the issuing of bonds necessary, shall communicate its determination to the common council. . . . In the event of the submission of the question of issuing such bonds by the common council . . . the failure to make said preliminary report to the common council by said board of public works shall be, and hereby is, cured, and all bonds that have been issued or may hereafter be issued . . . shall be valid to all intents and purposes and binding obligations upon the city issuing the same.

At the same time there was enacted another piece of legislation apparently needed to validate completely the prior bond issues. Act 32, P.A. 1911, provided that "whenever bonds for water works purposes have heretofore been approved by the requisite majority of the qualified voters of any city, as fixed by the several enabling acts under which the election was held, the said bonds, to the amount and for the purposes submitted to said voters, are hereby confirmed and validated." The second section declared that "this act is immediately necessary for the protection of the public health and safety."

World War I Legislation

During World War I the need for increasing water supplies and for furnishing water to industries and war workers living outside of corporate limits was reflected in the legislation of the period. Under Act 34, P.A. 1917, the municipal corporations authorized by law to sell water outside of their territorial limits might contract for such sale with cities or villages having authority to provide a water supply for their inhabitants. The act stipulated that the price charged should not be less than, nor more than double, that paid by customers within the territory of the municipality selling the water. The construction of water mains through the public highways of the city or village was permitted, if the consent of the local authorities having jurisdiction over the highways was obtained. The act also provided that where water was sold to outside purchasers, other than cities and villages, the municipal corporation owning the system should exercise the same powers and rights as it possessed within its territorial limits.

This act was quickly followed by Act 88, P.A. 1919, which authorized township boards to contract with cities or villages for the furnishing of water for fire protection and other purposes. The act provided for the creation of special assessment districts upon the filing of petitions signed by 60 per cent of the owners of record within the proposed district. The township was given the right to purchase, lay and maintain all the necessary pipes, connections and fittings. Half the cost was to be paid out of the contingent

fund of the township, with the balance to be raised by special assessments. The source of water was to be obtained by contract with the city or village possessing the utility.

Another law of importance was Act 119, P.A. 1919, which authorized cities having a population of 25,000 or more to institute proceedings to appropriate for public use the absolute title in fee to any privately owned public utility supplying water, light, heat, power or transportation to the municipality, provided the action was within the jurisdiction of the state constitution. The reasons for the passage of this act are not clear to the author, but it is quite evident that it permitted the municipal acquisition of privately owned public utilities.

Suburban Areas

Since World War I numerous statutes have been enacted which sharply reflect present-day thinking and the influence of real estate development, particularly in suburban areas. The legislation has primarily been concerned with townships and counties and with methods of financing. Act 116, P.A. 1923, provides that:

> In any township where there are platted lands, the plats of which have been duly approved and recorded, lying outside of the boundaries of incorporated villages, the township board shall have the authority to make improvements by constructing bridges, . . . grading, paving, curbing, . . . laying storm sewers, . . . constructing sanitary sewers and sewage disposal plants, . . . purchasing or constructing water works, . . . and making extensions of water mains to provide water for fire protection and domestic uses, or any combination of the foregoing, in any such platted land, and in unplatted lands adjacent or contiguous thereto; [and] to levy and collect special assessments to pay the cost thereof and to issue bonds in anticipation of the collection of said special assessments. . . .

This act requires the filing of a petition signed by the owners of record of 65 per cent of the land to be made into the special assessment district. The act has been amended on four occasions; at present, special assessments for any one year are limited to 15 per cent of the assessed valuation for any one improvement, and total assessments for any year may not exceed 45 per cent. Assessments for the purchase or construction of water works or sewage disposal plants may be divided into a maximum of 40 annual installments, but assessments for the construction of extensions of sewers, water mains and filtration plants are not to exceed 20 annual installments.

The "Metropolitan District Act" (Act 312, P.A. 1929) provides that any two or more cities, villages or townships, or any combination or parts thereof, can incorporate into a metropolitan district for the purpose of acquiring, owning, operating and maintaining, either within or without their limits, parks or public utilities for supplying sewage disposal, drainage, water and transportation. The district shall have a charter commission and a charter which shall include provisions for the nomination, election or appointment of officers; for the levying, collecting and returning of taxes; and for a sinking fund. The subjects of district taxation shall be the same as those for the state, county and school. The metropolitan district charter has to be approved by 60 per cent of the electors. In 1935 the act was amended to provide for revenue bond financing.

Revenue Bond Laws

The first revenue bond law was Act 316, P.A. 1931, which required that a municipal ordinance authorizing the issuance of revenue bonds must be approved by 60 per cent of the qualified electorate. It was apparently passed solely for the purpose of encouraging the construction of sewage disposal works, and the power of issuing bonds was given only to cities and villages. This act has not been used to any extent.

The revenue bond act responsible for much recent construction was Act 94, P.A. 1933. It has, of course, been amended several times, most recently in 1947. The act as it now stands authorizes public corporations to purchase, acquire, construct, improve, enlarge, extend and repair public improvements within or without corporate limits; to condemn property for public improvement; and to impose and collect charges, fees, rentals and rates for the services, facilities and commodities furnished.

The term, "public corporation," is defined as any county, city, village, township, school district, port district, metropolitan district or any combination thereof; "public improvements" are defined as garbage disposal plants, sewage disposal systems and water supply systems, including all plants, works, instrumentalities and properties used or useful in connection with obtaining a water supply, the treatment and distribution of water, and so forth. A bond-issuing ordinance is required to set forth a description of the project, its estimated cost, the amount of bonds, their maximum rate of interest, and time and place of payment. The bonds may be issued for not longer than 30 years and are tax-exempt. The principal and interest are payable solely from the net revenues derived from the operation of the improvement and are not a general obligation of the borrower. The ordinance authorizing the establishment of such a plan must be passed by an affirmative vote of a majority of the elected members of the corporation governing body, but there is a provision for a referendum upon petition by 10 per cent of the registered electors, if submitted within 30 days of the publication of the ordinance. In home rule cities a notice must be published in the newspapers 30 days prior to the adoption of the resolution or ordinance. If within that 30-day period a petition signed by not less than 10 per cent of the registered electors is presented, the legislative body must submit the question of the issuance of such revenue bonds to the electors for approval by a 60 per cent vote. The 1947 amendment permits the powers granted by this act to be exercised whether or not any bonds are issued under its provisions.

County and Township Boards

The need for developing water systems outside of corporate limits influenced the passage of Act 342, P.A. 1939, which grants to the county board of supervisors the right to adopt, by a majority vote, a resolution authorizing and directing the establishment of water systems, sewer systems, improvements and services between cities, villages and townships. This act virtually puts the county into the water and sewer business in Michigan by providing that it can enter into an agreement with units of government desiring services, allowing the issuance of self-liquidating bonds to finance the improvement and vesting authority in a committee of three members of the

board of supervisors, in the county road commission, or in the county drain commissioner. Payment of the bonds is to be made from tapping charges, rates and other charges or assessments necessary.

In 1941 interest turned to the acquisition of water supply systems for townships. Act 47, P.A. 1941, provides that the township board:

. . . shall have the authority to contract with the governing body or other agency operating [a] water department or district for the purpose of securing extensions or further extensions of water mains throughout portions of the township and to provide water service by the continued operation of such mains by such municipality or the water department or district. The township board may make, levy and collect special assessments to provide the necessary money to carry out the terms of such contract and to issue bonds in anticipation of the collection of such special assessments.

A special assessment district can be created upon the receipt of a petition signed by the owners of record of at least 51 per cent of the land within the assessment district. No special assessment may be levied upon the property in excess of $1.25 per front-foot in any one year. Assessments can be divided into a maximum of ten annual installments.

In the same year the township was given the ability to create a water district through voluntary financing. Act 107, P.A. 1941, provides that:

. . . upon filing with the township clerk of petitions . . . signed by 60 per cent of the record owners of the land to be made into a township water supply district, the township board . . . shall have the power to contract with any city or village for the furnishing of water for fire protection and domestic purposes to such water supply district under such terms and conditions as may be agreed upon between said township board and the common council or other representative body of the city or village.

Not more than 50 per cent of the net cost, exclusive of federal aid, can be paid out of the contingent funds of the township, the remainder to be raised by voluntary payments by property owners in the water district. Failure to raise the money on a voluntary subscription basis by a definite date invalidates the project, and no tapping can be made without first paying the fee. Provision is made for the township board to install and maintain the improvement as well as to take over any mains similarly installed prior to the action contemplated by the act.

Act 235, P.A. 1947, which became effective October 11, 1947, provides for separate or joint ownership of water or sewage disposal systems within two or more public corporations. In addition to the county, metropolitan district and city, "public corporation" includes the village or township when, by subsequent incorporation, a part of the system lies within it. To acquire the system within a newly incorporated area, a 60 per cent vote of the electors is necessary. Outstanding revenue bonds must be protected through the issuance of joint or separate refunding bonds or through the assumption by each corporation of its portion of the debt. Non-callable bonds not surrendered will have priority on the revenue. After all outstanding bonds have been paid or the priorities guaranteed, the corporation may take over the ownership and operation but must secure to all subdivisions the connections, flowage rights and other facilities necessary for the operation of their systems. The utility

can be operated as a single unit, under a joint board or with one public corporation as agent for all.

Conclusion

From the acts discussed in this paper, it is evident that water legislation has never been lacking in Michigan. At times it has required urgent necessity to hasten the passage of laws, but the delay in obtaining legislation has not been a serious handicap to the development of water supplies. Today the legislative machinery is available; it is only a question of convincing the public officials of the need for furnishing a public supply to the urban population, whether it is located in incorporated cities, in villages, in the fringe area around the incorporated municipality or even at a resort lake or other vacation spot consisting merely of a large group of cottages. With the recent plotting and development of suburban areas, it is necessary for townships to adjust their thinking and for township boards to adopt city methods of managing public utilities.

Public Water Supply Legislation in Idaho

By H. C. Clare and Robert E. Smylie

A paper presented on May 16, 1947, at the Pacific Northwest Section Meeting, Victoria, B.C., by H. C. Clare, State Public Health Engr., and Robert E. Smylie, Attorney General, Boise, Idaho.

IDAHO'S public water supply legislation is restrictive or liberal, depending on the point of view of the person looking at the law.

During the war years, of course, the problems of construction, maintenance and equipment of public water supplies were in the same state of quiescence in Idaho as elsewhere. But with the coming of peace, Idaho cities and villages have again given consideration to attaining adequate water supplies. The first obstacle was, as usual, the financing of improvements.

Idaho municipal corporations have long had the power to issue coupon bonds to purchase or otherwise acquire a water works plant and all the necessary equipment and attachments. It has been questioned whether a bonded indebtedness thus incurred was subject to any limitation based on the value of the property. Water works authorization was once included in a general bonding statute which permitted a maximum indebtedness of 10 per cent of the value of the property involved. In 1913 the legislature removed water works from this statute and made them the subject of a separate section in the code. This would imply strongly that the 10 per cent limitation was left behind in the older law, a line of reasoning upheld by the Attorney General in 1935. The question continues to linger, however, although the authors know of no reported court decision which has discussed it.

The 1913 act has been variously amended and was most recently the subject of legislative attention in the session of 1933. In that year a detailed statute was passed authorizing cities and villages to issue *negotiable revenue bonds* for water works purposes, declaring a statutory lien and including all the other usual items. This statute was a companion piece to one making the same provisions applicable to sewers, sewer systems and treatment plants. These laws would have been definitive except for an obscure and much-discussed provision in the Idaho constitution.

Constitutional Restrictions

The state constitution is a most complex document. The convention assembled at a time when the desire to write deep-rooted and stringent restrictions into the basic law was at its height. The section on municipal indebtedness is extremely sweeping and rigorous. Briefly stated, it provides that no municipality may in any year, for any purpose, incur an indebtedness or liability which exceeds the income and revenue provided for that year, without the approval of two-thirds of

the qualified voters *and without levying an annual tax to retire the obligation in twenty years.*

Similar provisions exist in other constitutions, but they are not worded in such restrictive terms. In some states the courts have adopted a construction which makes possible the issuance of revenue bonds. In other states the constitution has been amended to allow such bonds to be issued. The usual reasoning behind the approving decisions is well expressed in the Washington case of *Winston* v. *Spokane,* which adopts the common approach that a revenue bond does not create an indebtedness or liability within the meaning of the constitutional provision.

Revenue bonds for water works have from time to time been passed on by attorneys for the bonding companies and the abstracts of proceedings approved on Idaho issues, but similar issues have been rejected on the ground that the legislature is without power to authorize such obligations. To the extent that this situation produces uncertainty it is a restriction on the growth of a satisfactory system of municipal water works. The theory that revenue bonds issued by municipalities may be unconstitutional is based on a decision of the supreme court announced in 1912 by the late Justice Ailshie in *Feil* v. *Coeur d'Alene*. The question of constitutionality was not directly decided, but there is a strong indication that, if it had been, the court would have held the statute of 1933 to be beyond the authority of the legislature. The basic doctrine laid down in 1912 that revenue bonds did create an indebtedness was reiterated in a decision in 1934 involving the same city but a different statute. It therefore appears that the Idaho courts favor a doctrine which is not in accord with the majority of the judicial decisions in other states. The principle has been contentious from the first, and a strong current of dissent exists.

The net effect of this confusion of authority is to render revenue bonds a hazardous, and thus ineffective, mode of dealing with the problem of financing municipal water works. An attempt was made by the Dept. of Public Health, the Idaho Municipal League and interested groups in the 1947 legislature to secure the approval of a resolution proposing an amendment to the constitution which would remedy this defect. The attempt was unsuccessful, but apparently because of collateral considerations.

Use of Surplus Funds

As a consequence of this uncertainty about the use of revenue bonds to finance water works and other civic projects, numerous cities have fallen into the practice of applying the surplus funds from their water works operations to other departments of the municipal governments. This matter never seems to have been taken up by the legislature. In the absence of any express mandate, the city authorities have taken the position that the water works surplus reverts to the general fund and is expendable in the same way as are other general fund moneys.

The growth of this practice and the current dissatisfaction with it may lead to a consideration by the legislature or the courts of the problem presented in *Mayor of Haverhill* v. *Water Commissioner of Haverhill* [320 Mass. 63, 68 N.E. (2nd) 188 (1946)]. There is a growing determination on the part of interested persons in Idaho to take steps to protect the integrity of

water works funds, so that the surplus may be expended for deferred maintenance. No statutory authorization for such a procedure exists, but neither does the law demand that the funds thus accumulated remain inviolate. The tendency, however, is to feed these surpluses into the always needy coffers of street maintenance, police and other nonrevenue-producing municipal departments. Some day the growth of Idaho's towns will make it necessary to face this problem with complete candor. Even then there will be difficulties, as the administration of the water systems will almost always be under the city councils, which are now the principal raiders of the water works funds.

An approach to this problem may perhaps be found in a new law enacted by the 1947 legislature which provides for the creation and maintenance of water and sewer districts as tax-levying bodies corporate. These districts, once organized, will have as their chief purpose the construction, operation and maintenance of water and sewer systems. They can properly be created without reference to existing city or county boundaries and have the power to issue general obligation bonds, levy taxes and perform all acts required by the functions assigned them by law. Some of the smaller communities can become a part of these districts, in which event surplus funds arising from their water works operations will be exclusively dedicated to the systems set up by the districts.

Public Health Measures

Another recent enactment of the legislature is of interest. Heretofore, there has not been much legislation on the subject of stream and water pollution, with the exception of miscellaneous statutes forbidding, in a limited way, certain types of industrial pollution. Some Idaho valley areas contain population and industrial complexes which may soon create definite hazards from human and industrial stream pollution. In two or three places, small streams have already become virtual open sewers. Desiring sufficient information to attack these problems sensibly, the legislature created a Water Utilization Committee which is composed of representatives from the Fish and Game Service and the Departments of Public Health and Reclamation, as well as six members chosen from interested public and industrial groups. Gov. C. A. Robins has appointed the committee, which is directed to study the question, make recommendations concerning the industrial and human consumption of water resources and report on the possible methods of preventing the pollution of streams by any kind of waste. The committee is instructed to approach the problem from industrial, human and recreational points of view and to propose legislation to accomplish its recommendations. Beneficial results can be achieved.

It appears, therefore, that Idaho legislation on water supply is not definitive and that much remedial action is necessary. That these problems, so closely allied to the general welfare of the whole people, are at last becoming a part of the conscientious citizen's everyday thinking, is a most hopeful sign. Even now, pure water and decent sewage disposal are items on the agenda of nearly all Idaho city councils.

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *B.H.—Bulletin of Hygiene* (*British*); *C.A.—Chemical Abstracts; Corr.—Corrosion; I.M.—Institute of Metals* (*British*); *P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research* (*British*).

WATER QUALITY

Criteria of Water Quality. RUDOLPH E. THOMPSON. Wtr. & Sew. **83**:9:32 (Sept. '45). Earliest water qual. stds. based upon content forms of nitrogen and org. matter, and such tests still most useful in providing information of supplementary nature, particularly where correlations have been established with bact. qual. Fluctuations from normal, however, usually more significant than abs. amts. present. Chlorination has reduced dependence upon such indicators of water qual. in so far as treated water concerned and recent improvements in o-t. test have increased reliability of information provided by that control procedure. Final judgment must be based upon bact. findings, except in case of toxic chem. constituents. Practice of including limiting bact. count now largely abandoned and present-day stds. usually phrased in terms of coliform bacteria. Here again indirect measure of water qual. employed, but remarkable decline in typhoid testifies to adequacy of stds.—*R. E. Thompson.*

New Index of Water Contamination: The Bromine Number. S. R. CHIRKOV. Gigiena i Sanit. (U.S.S.R.) **12**:7 ('44). Amt. of oxidizable org. matter detd. by titration at room temp. with NaOBr, about 0.002 *N*, in H_2SO_4. Br number b expressed in mg. equiv. per l. water. In addn. to org. matter, inorg. sulfides, nitrites, and Fe^{++} compds. consume Br, but they are negligible in comparison with org. matter. b corresponds to amt. of most active org. matter present at each stage, while $KMnO_4$ oxidizability k is index of org. matter reacting only with energetic oxidants. Ratio $a = (100–8b/k)$ plotted against s, deg. of O satn., linear. An s of 100% corresponds to an a of 1.2% representing upper permissible limit of org. matter. Excess expressed by $v = (665\ b/k) - 1$, termed activity coefficient of org. contamn. v proved to be very sensitive index of contamn. of rivers with fresh fecal matter (v values up to 3.0). Convenient measure of progress of aerobic self-purif. Values of $v > 1$ indication that water objectionable.—*C.A.*

The Value and Importance of "Limiting Concentrations" in Determining the Hygienic Quality of Water. Part I. H. BEGER. Kleine Mitt. Mitglied. Ver. Wasser-, Boden-u. Lufthyg. (Ger.) **18**:115 ('42); Zentr. ges. Hyg. (Ger.) **51**:9 ('43). Content of inorg. nitrogen, "org. matter," chloride, iron, manganese and dissolved gases in water has no direct connection with its hygienic qual., but concns. of some of these substances can be used as indications of qual. of water. No exact limiting concns. can be given which divide pure from impure waters, but there are approx. avg. values which indicate satisfactory water. Water considered of good qual. when it contains at most only traces of ammonia and nitrite (except in case of ground waters contg. iron), phosphate and compds. of potassium, and when it contains, per liter, not more than 10 mg. of nitrate, 12 mg. of org. matter (expressed as consumption of potassium permanganate), 30 mg. of chloride (as chlorine) and 60 mg. of sulfate (as SO_3). Total hardness should not exceed 15° (Ger.) and residue on evapn. should usually be less than 500 mg./l. Value of pH usually of importance only if lead pipes used for distr. of water, when there is danger of lead poisoning. —*W.P.R.*

Army Water Supplies in the United States. ANON. U.S. Army Med. Dept. Bul. 85, p. 26 (Feb. '45). Under program of water qual. control established by San. Eng. Div. of Preventive Medicine Service, less than 2% of 20,000 samples of water per mo. now being examd. is unpotable. Essential steps in program include: (1) establishment of safe bases of design and their use by corps of engrs.; (2) san. surveys by san. corps engrs. to det. such defects as actual or potential cross-connections, improperly protected wells, unsafe sources of supply and hazardous practices; (3) institution of adequate chlorination; and (4) provision of routine regular bact. examn. Closest cooperation maintd. with corps of engrs., especially R. and U. branch. Actual performance of program delegated to service commands, which are responsible for constant improvement maintd. Service command san. engr., who is staff officer of service command surgeon, supervises work in respective service commands.—*Ed.*

Exposure to Lead. ROBERT A. KEHOE. One of a series of articles presented at the Conference on Lead Poisoning, 7th Annual Congress on Industrial Health (1946) and reprinted in booklet form from Occupational Medicine **3**:13–19, 77–83, 135–171 (Jan., Feb. '47). Reprint reviews exposure of general public and also industrial workers to lead. Lead content of inspired air from atm. in city of Cincinnati found to be equiv. to 0.1 mg./day per capita. This source of lead apparently accounts for fact that avg. excretion of lead exceeds intake in food and beverages by small amt. Lead content of various foods avgs. about 0.30 mg./day per capita, apples having highest lead content because of use of lead-bearing insecticides in orchards. Beverages vary in lead content to marked degree. Water supplies of 36 scattered cities contained 0.003 to 0.04 mg. of lead per l., avg. value being 0.01 mg./l. Lead content of water flowing from plumbing fixtures of new bldgs., however, as high as 0.92 mg./l. due to use of lead-bearing luting compds. This source of lead persists for only short time after bldg. occupied. In contrast, beer contains 0.13 to 0.29 mg./l. and wine 0.05 to 1.51 mg./l. Lead, generally speaking, considered to be accumulative poison. It has been shown, however, that amt. of lead excreted exceeds amt. consumed in food and beverages, provided total consumption below 0.3 to 0.6 mg./day per capita. Permissible limit for lead content of potable water given as 0.1 ppm. by Drinking Water Standards of U.S.P.H.S. Assuming consumption of 2 l. of water per capita per day, lead intake with this content would be 0.2 mg. per capita. In view of unavoidable lead content of certain beverages, efforts should evidently be made to maint. present low content of lead in public water supplies. Potable waters should contain even less lead than given in Drinking Water Standards. Remaining portion of paper devoted to exposure of certain industrial workers to lead.—*C. R. Cox.*

Transfer of Lead From Water to Food and Drink. A. SEISLER, A. NECKE & H. WEBER. Arch. Hyg. Ber. (Ger.) **128**:196 ('42); Wass. u. Abwasser (Ger.) **41**:38 ('43). Lead may be dissolved by water as it flows above or below ground or from materials contg. lead after water has been removed for supply. In certain lead regions and in industrial dists. considerable stretches of streams may contain lead; examples in Germany are the Bleibach in the Rhineland, the Innerste, the Oker and the Bönkhauser Bach. When such streams overflow their banks, sludge cont. considerable amts. of lead deposited in fields and increases concn. of lead in fodder crops. Many instances of lead being dissolved from lead pipes, but problem of aggressiveness of water to lead not completely solved. Cases of lead poisoning occurred in Heligoland where rain water distributed in lead pipes; lead dissolved from lead linings of water storage tanks as well as from lead pipes. Rate of flow, temp. and oxygen content of water all affect plumbosolvency. Lead may be transferred from water to food and drink during their prepn. Kruse found that in prepn. of tea and coffee nearly 90 and 50% respectively of lead in water remained in liquids. Filtration of coffee removed some lead. Haupt suggests possibility that in foods which contain org. compds. of sulfur the lead may be converted to slightly soluble compds. of lead and sulfur. Author prepd. tea and malt coffee with, and cooked potatoes in, water contg. 0.5, 1, and 2 mg. of lead per l. Some of lead adsorbed by filter paper when water filtered. Boiling water rendered considerable proportion of lead insoluble. With tea and malt coffee 70 to 80% and 35 to 45% respectively of lead in soln. remained in liquids. When potatoes cooked in their skins, 70 to 80% of lead in water absorbed by potato; of lead

absorbed 90% found in skin and 10% beneath skin. When peeled potatoes cooked, about 50% of lead in water absorbed.—*W.P.R.*

Certain Relations in the Chemical Processes in the Underground Waters of the Kara-Tau Range. A. A. Konoplyantsev & V. I. Knauf. Compt. Rend. Acad. Sci. U.R.S.S. (U.S.S.R.) **53**:63 ('46). Differing intensities of tectonic movements have resulted in different rates of karst formation within limestone-dolomite Tamda series, principal aquifer of Little Kara-Tau Range. In areas of greatest uplift, high rate of karst formation has been accompanied by greater soln. resulting in underground water poor in sulfate ion. Areas of little uplift are characterized by waters high in sulfate and Mg ions and with greater mineralization and hardness.—*C.A.*

The Influence of Climate on the Chemical Composition of Vadose Ground Waters. H. Schoeller. Bul. Soc. Géol. France (Fr.) **11**:267 ('41). In addn. to petrographic condition of subsoil, climatic factors such as amt. of pptn., evapn. and avg. yearly temp. influence compn. of ground water. When waters from same mineral strata compared, Ca, Mg, Na, Cl and SO_4 concns. increase from France through Tunis to steppes of Sahara as rainfall simultaneously decreases and evapn. increases. In equatorial region of high rainfall and strong leaching of soil strata, waters low in salt content again found. Combined CO_2 content shows no great variation, because CO_2 tension in soil strata approx. same everywhere. As result of limited soly. of $CaSO_4$, Cl concn. increases more rapidly than SO_4 concn. High ratio of Mg/Ca usually result of soln. of $MgSO_4$.—*C.A.*

The Upper Salinity Content in Water for Irrigation. From Notes Supplied by J. D. Lang. Wtr. & Wtr. Eng. (Br.) **50**:398 (Aug. '47). Salinity of ground water in Australia varies enormously. No std. limits set for salinity of water. Tabulated figures give some idea of salinity values used for domestic and stock purposes.

Use	Total Dissolved Solids *ppm.* Good	Poor	Limit
Human consumption	300	1500	6000
Horses—working		2500	5000
others			12000
Cattle		3500	9000
Sheep		9000	18000

Water for irrigation should contain not more than 700 ppm. total dissolved mineral matter in which NaCl predominates. Limit likely to vary considerably, depending on soil and crop characteristics, annual rainfall and drainage.—*H. E. Babbitt.*

SOFTENING AND IRON REMOVAL

Louisville's Softening Program. Anon. Am. City. **62**:11:104 (Nov. '47). Ohio R. source of water for Louisville, Ky., more pold. than Louisville's own sewage after complete treatment. In addn. to poln. load, this water sometimes contains strong tastes and odors and considerable hardness. Begun in '09, treatment plant now has total filter capac. of 120 mgd. and raw water reservoir of 100 mil.gal. Recently completed improvements reduce max. hardness of 187 ppm. to 50–80 ppm. Softening equip. consists of mixing and clarifying basins, chem. conveyors and feeders. After alum clarification, water mixed with lime and soda ash, flocculated, settled and filtered. During normal year 120 tons alum, 50 tons ammonium sulfate, 2900 tons lime and 1200 tons soda ash used. Water for lime slaking and soda ash soln. heated to overcome differences in raw water temp. Excess alky. corrected with CO_2 generated in oil-burning generators of 15,000 lb. per day capac. CO_2 compressors unnecessary because air supplying generators compressed.—*F. J. Maier.*

Research With Base-Exchange Materials. Ed. Jaag. Textil-Rundschau (Swiss) **1**:99 ('46). Method for detg. exchange capac. of base-exchange materials described. App. consists essentially of heavy-walled glass tube 2 cm. in diam. and 20 cm. long, with stopcock at lower end. Connection made with supply of hard water through glass tube passing through rubber stopper closing upper end of tube. Effective ht. of column of material 15 cm. Uniform downward flow of 0.5 l./hr. used. This gave contact period of same order of magnitude as that used in practice. Lower rate than this offered no advantage and higher

rate gave lower values for exchange capac. Comparative tests showed that results same for water pressures of 6 atm. as for pressure of 1 atm.; latter pressure used as being more convenient. Material regenerated (after backwashing) by treatment with NaCl soln. (downward flow used). Hardness detd. by method of Boutron and Boudet. Water used had initial hardness of 20° (French), and end point taken not as first detectable hardness, but as point at which hardness of effluent reached 10°. Quant. of water so softened taken as measure of exchange capac. of material under test. Graphs reported show that hardness increased very rapidly as soon as it was no longer 0. Tests run on number of commercial materials, including natural and artificial zeolites, artificial resins and materials having activated-C base. As exchange capac. of fresh materials higher than that of regenerated materials, values used were a mean of those obtained after the 3rd and 4th regenerations. In general, artificial resin material showed very good exchange capac. and artificial zeolites good capac., while materials having activated C-base were intermediate between these two. By repeated use of NaCl soln. for regeneration, saving of up to 40% in NaCl realized, compared with single use and discarding of soln. When used only once and discarded, 4–5 times theoretical amt. of NaCl required. Results obtained with this method agree well with those obtained in practice.—*C.A.*

Particular Properties of the Hexametaphosphate Ion. P. NAVET. Tech. l'Eau (Belg.), p. 11 (June '47). Expts. show that hexametaphosphate ion forms a complex stable compd. with iron. This complex stable in presence of Na_2CO_3 and NaOH. Addn. of 5 ppm. sodium hexametaphosphate in presence of Na_2CO_3 and pH 10–11 prevents pptn. of Fe or Mn. Use of $Na_6(PO_3)_6$ in mineral waters prevents changes during storage. Result is no iron in ppt., no H_2S oxidized or CO_2 removed, and better and more agreeable beverage for consumer. It has been found that addns. of hexametaphosphate reduce deposits and probably diminish oxidation by air. Water of the Source Marie-Henrietta Spa contains 21 ppm. Fe and dry residue 130 ppm., to which 100 ppm. hexametaphosphate added. Mineral water at Pouhon Pierre-le-Grand Spa contains 16.5 ppm. and dry residue 510 ppm. Fe, to which 1000 ppm. hexametaphosphate added. Storage of these waters in bottles, daily agitated, showed no deposit after 2 mo. Commercial hexametaphosphate contains also *o*-phosphate and some pyro-phosphate.—*W. Rudolfs.*

New Process for the Removal of Iron and Manganese From Water. RAIMUNDO ISALO VIEIRA. Rev. Quím. Ind. (Brazil) **16**:177:25 ('47). Flax straw treated 3 times with boiling water and then broken absorbed Fe and Mn from water in lab. expts. Absorption ascribed to lignin of straw. Also other lignin-contg. materials, e.g., sawdust, used successfully.—*C.A.*

Incrustations in Water Pipes as Affected by Filamentous Iron Bacteria. S. C. PILLAI, R. RAJAGOPALAN & V. SUBRAHMANYAN. Indian Med. Gaz. (India) **82**:36 (Jan. '47). Character and compn. of water and nature of pipe material important factors in control of incrustations and other biol. growths in water mains and distributing pipes. Observations made in India, e.g., Madras and Negapatam, show that considerable amt. of reddish-brown material forming small masses of flocculent character present, floating on water, and also present on incrustations in water pipes. Examns. of this material revealed that it is largely composed of species of filamentous iron bacteria [*Leptothrix ochracea*?]. Uniform coating of about ¼" thickness developed on inside of water pipes in course of month, but did not reveal any appreciable corr. of pipe material. Appeared that incrustation formed had derived its material largely from water. Filtering water through sand and "leaf filter" removed about 45 and 41% of iron and 43 and 28% of silica, resp. Further investigations under way regarding iron-bearing waters and their treatment for various uses.—*P.H.E.A.*

Iron in Water From Gravel. G. VAN BENEDEN. Tech. l'Eau (Belg.), p. 11 (Oct.' 47). When water level high in gravelly wells water clear and does not flocculate; when low, water contains iron, and iron salts flocculate. Amt. of iron is 1 ppm. Rate of flocculation indicates that iron is in form of $Fe(HCO_3)_2$. Waters contain biol. and meteorologic CO_2 sufficient to bring 1 ppm. Fe in soln. and also form $Ca(HCO_3)_2$. Why should CO_2 bring into solns. exactly 1 ppm. Fe, which does not change during pumping or when CO_2 increases? If it is assumed that H_2SO_4 interferes, problem becomes clear. Traces of

H_2S will permit traces of CO_2 to dissolve 1 ppm. Fe. When water partly stagnant, $Fe(HCO_3)_2$ would be formed spontaneously, but when aerated by pumping or rapid replenishment, no $Fe(HCO_3)_2$ formed, or oxygen of water retards active flocculation of Fe. —*W. Rudolfs.*

Concerning the Presence of Iron in Waters From Certain Wells. J. DELECOURT. Tech. l'Eau (Belg.), p. 11 (Sept. '47). In number of cases artesian water from calcareous strata takes up iron in distr. system, and under same conditions water contains aggressive CO_2. Water obtained from depth of 180–200 m. in chem. equil., contains no aggressive CO_2 and has normal temp. of 16°C. About 20 m. below surface, temp. of water 10°C.; when water pumped, chem. equil. existing at 16°C. broken. Quant. of CO_2 in equil. less at 10°C. than at 16°C. so that water becomes aggressive. CO_2 attacks pipes; small part of iron changed to iron bicarbonate, but most of iron in soln. Reservoir water contg. no aggressive CO_2 decreases in temp. in distr. system with liberation of CO_2. In case reservoir water contains insufficient CO_2 for equil. reaction, pipes automatically protected against corrosion. Warmer reservoir water means better protection.—*W. Rudolfs.*

The Conditioning of Water for Flooding at Tuimazy. B. G. LOGINOV & A. A. MARAKAEV. Neftyanoe Khoz. (U.S.S.R.) **25**:2:29 ('47). Trivalent iron salts resulting from corrosion of piping by water pumped from river near Tuimazy field cause fouling of injection wells. This injurious effect prevented by acidifying water to pH of 3.4 or less.—*C.A.*

FOREIGN WATER SUPPLIES—GENERAL

How Water Came to an Australian Desert. JOHN LOUGHLIN. Wtr. & Wtr. Eng. (Br.) **50**:297 (June '47). Southern part of South Australia well watered and rich in vineyards and crops. Northern part dry, particularly near shipbuilding town of Whyalla. 30" concrete-lined steel tube, 223 mi. long, costing £3,122,000 crosses from Murray R., northwest to Spencer's Gulf and thence to Whyalla. Similar 50-mi. pipeline on Eyre's Peninsula in S. Australia, and 350-mi. all-welded line in Western Australia carries water from Mundaring Weir to Kalgoorlie on western fringe of desert. Before coming of pipeline, Whyalla water supply came from two 20-mil.gal. reservoirs. Pipeline delivers 1200 mil.gal. per yr. to town and 900 mil.gal. per yr. to rural districts on way. Distributed in town at charge of 3s 6d. per 1000 gal. (Imp.). Primary pumping station at Morgan where water screened through fine wire-mesh revolving screens. Three other pumping stations lift water to Hanson, el. 1658 above sea level, distance of 61 mi. Over remaining 162 mi. water flows by gravity to Whyalla. 27 concrete tanks along route have total storage capac. of 44 mil. gal. Main purpose is to reduce presure to safe limits. Water supplied to landholders along line.—*H. E. Babbitt.*

Importance of Rural Water Supply in Austria. V. ZATLOUKAL. Gas, Wasser, Wärme (Austria) **1**:219 ('47). Although all cities over 10,000 people have water supply systems, there are between 10,000 and 11,000 communities without such supplies. Planning for rural and suburban supplies in hands of government, which advises communities, makes plans and supervises constr. There are 385 projects under way (17 under constr., 305 plans ready, 31 delayed because of lack of materials). There are over 1400 supply systems and 50 distr. projects on boards. In Austria alpine climate and mountains dominate country. Pptn. varies from 500 mm. in east to 3000 mm./yr. in Alps. Since ground water quant. depends on geology of region, and type of mountain masses vary, wells and ground water vary materially from place to place in relation to permeability and rainfall. Country can be divided in 5 areas: (1) impermeable primitive rock with many shallow, high, isolated wells which react rapidly with pptn.; produces soft water; (2) permeable limestone with few, isolated wells high in mountains and large wells in valleys, which with heavy rain or thaw frequently become turbid; produces medium hard water; (3) impermeable sandstone and gossan formations similar to (1), but water hard; (4) hill and deep tertiary sediments with mostly limited supply and rolling country with alternating sand and clay layers, also artesian water; (5) diluvium and moorlands of valleys and flat areas with abundant supply. Unequal distr. of water results in insufficiency for certain areas of country, so that long-distance transportation required. Areas with

abundant subsurface water lie along Donau and tributaries, whereas excessive deep well water found in limestone alps. In planning sufficient supply for whole country, available sources as well as varying conditions of country must be considered. Supplies are to be based upon: (1) household use (drinking, cooking, washing 30–50 l.; water closets 30 l.; baths 20 l.; cattle and horses 50–80 l.; hogs, sheep, goats 10–15 l.; gardens 2 l./sq.m./day); (2) public use (streets 1 l./sq.m., public baths 300–500 l., showers 100–200 l., fountains 8 l./min.); (3) special supplies (small gardens 2 l./sq.m., cooking and dairy 4–6 l./l. milk produced; vineyards 600 l./acre, domestic drinks production 40–60 l./day, visitors 100–300 l./day). Government has also promulgated rules and regulations for industrial supplies, but leaves planning to private engrs. Government aids communities by giving noninterest-bearing loans up to 40% of cost, to be repaid pro rata in 100 mo. Private water companies obtain grants of 20–30%. Result of short-term loans has been that communities, to avoid undesirable credit conditions, have formed water companies and thereby obtained grants. Objection is that a water company cannot compel connection to system. New law proposed to avoid flaws in present laws.—*W. Rudolfs.*

Public Water Supply of Brussels. G. Haquenne. Tech. l'Eau (Belg.), p. 21 (July '47). Water collected from sand, limestone and alluvial soil. In sand, more important collecting system is through drainage galleries extending for several km. in aquifer. Galleries are ovoids about 70" high. Second source cylindrical filtration wells, 20–40" in diam. Collection in calcareous terrain in most cases is in galleries located on side of hills, and water transported through canals in rock. To prevent contamn., canals constructed some distance from river, and "barriers" of plastic soil or concrete placed between river and canals. Galleries in 3 collecting regions have length of about 8.5 km. Water from alluvial soil collected from wells of varying depth and capac., ranges from 15,000 to 35,000 cu.m./day. Water qual. supervised by chemists at central lab.; disinfection by chlorine and ammonia.—*W. Rudolfs.*

Water and Fountains of Paris. M. P. Leon. L'Eau (Fr.) **34**:96 (Aug. '47). City of Paris located on island in middle of river, had no water for over 5 centuries. There were some wells in cellars of homes in 1870; during siege of Paris, water detestable, heavily pold. from outhouses and cemeteries. At end of 8th century some aqueducts built, remainders of which still extant. Collection basins closed with copper or lead covers with circular openings. Smallness of basins required extreme parsimony; water barely sufficient for 2000 people, whereas at end of 14th century Paris had 275,000 inhabitants. During religious wars aqueducts fell into decay. Paris had no supply other than pits dug along Seine; poor and highly pold. water. In 1602, Henry IV had pump constructed at Pont-Neuf, which novelty caused great enthusiasm. Because of river stage and height of river banks, pump operated only on certain days. Louis XIV constructed great water works for Versailles, but until end of 18th century Paris inhabitants could not obtain more than 2 l. per capita daily. After fire pump inventions of Papin and James Watt, distr. for domestic purposes attempted and half a dozen fountains built. Napoleon solved problem by constr. of canal and reservoir supplying 100 l. of water per capita; many public fountains built. By end of 19th century systems enlarged. Water treatment consisting of filtration and chlorination has permitted use of Seine water, so that at present some 400 l. per capita available. Many fountains now used only for decoration. —*W. Rudolfs.*

Notable Water Undertakings. IV. Bradford [Gr. Br.]. Anon. Wtr. & Wtr. Eng. (Br.) **50**:300 (June '47). Before 1855 many townsfolk drew water from wells and springs. In 1858 public supply gave out. Nidd scheme, started in 1893 with compensation reservoir at Gouthwaite and Nidd aqueduct, completed in 1900. Angram Res., started in '03, completed in '16. Scar House Res. completed in '36. Dam 1825' long and 231' high forming reservoir with capac. of 2200 mil.gal. (Imp.). Whole water supply by gravity. Over 22 mil.gal. (Imp.) now supplied by Bradford water works.—*H. E. Babbitt.*

Problems in Northern Ireland on Water and Sewerage Schemes. R. E. D. Bain. Surveyor (Br.) **106**:407 (Aug. 8, '47). In '39 although most larger towns possessed good piped supplies these were showing signs of inadequacy. There are 69 statutory water and sewerage authorities in province and 2 non-statutory undertakings. In '39 several schemes about to be commenced canceled

on account of war. Water Supplies and Sewerage Act passed in Dec. '45. Important provision giving govt. power to assist local authorities in water and sewerage schemes by substantial grants. Close cooperation between local engrs. and ministry's engrs. has been fostered. Good progress has been made with designs and contracts for laying trunk mains. Basic principle in design is that no pipe shall be laid which is incapable of meeting entire water requirements of area through which it passes. In most schemes water for domestic use has been calcd. on 35 gal. (Imp.) per capita in rural areas and 40 gal. in towns.—*H. E. Babbitt.*

Water Supply in the Middle East Campaigns. IX. Palestine. G. L. Paver. Wtr. & Wtr. Eng. (Br.) **50**:381 (Aug. '47). Topographically Palestine falls naturally into 5 zones: (1) Coastal Plain, (2) Mountain Uplands, (2a) Mountain Borderland, (3) Dead Sea Rift Valley, (4) Sinai Desert and (5) E. Negeb Area. In (1) annual rainfall approximately 28″. Recent sediments of considerable thickness constitute excellent aquifer. Properly constructed 10″ boreholes yield 10,000 to 20,000 gph. (Imp.). Qual. good. Rainfall in (2) reaches 40″ a little north of Jerusalem. Area comprises 60% of total area of Palestine and receives 75% of rainfall. In higher rainfall areas of N. Galilee supplies plentiful, but in Judea and Samaria, often inadequate. Zone (2a) constitutes transition from coastal plain to upland limestone area. Yield of bores more problematical but yields of 1000 gph. (Imp.) have been obtained. No underground water development took place in area (3). Rainfall in area (4) about 8″ but drainage derived from slightly higher rainfall zone, and yields of 1000 gph. have been obtained. Area (5) difficult of access. No water development took place but reconnaissance surveys carried out. Geological structures potentially favorable for moderate supplies from medium to deep boreholes.—*H. E. Babbitt.*

Government Aid for Potable Water Supplies in the Netherlands. W. F. S. M. Krul. Water (Neth.) **31**:183 (Sept. 4, '47). Local authorities together with provincial and state control water supply systems. In '45 some 763 communities (75% of total), supplying 90% of all potable water, connected with centrally controlled systems. In western part of country, 95% connected with central systems. Many munic. supplies interconnected on provincial basis; this method allows rural communities to obtain water at reasonable rate. Although difficult to construct supply systems for entire rural area, general plan has been set up to spend 30,000,000 guilders for this purpose. One of greatest difficulties is to supply sufficient water, particularly in western part of country where pop. density is 1800/sq.mi. Hydrological condition in this area poor because ground water mostly brackish, while larger rivers, especially Rhine, pold. by French and German industries. Well waters must be resorted to and transported considerable distances. At present all 205 water supply systems (15 privately owned) members of trade organization and technical personnel organized in Netherlands Water Works Assn. —*W. Rudolfs.*

Bird's-Eye View of the Water Supply in the Netherlands. B. F. Van Nievelt. Water (Neth.) **31**:187 (Sept. 18, '47). In Feb. '47, Netherlands had 9,552,000 inhabitants, or density of 725/sq.mi. Density in western part of country about 1820/sq.mi. The 203 public water supplies produce about 250 cu.m. water a year. Of total pop., about 75% supplied by public enterprises; sources of water: 32% ground water from dunes, 47% from wells and 21% from surface waters. In spite of lack of sufficient theoretical hydrological information, Dutch have developed modern theory fit for practical utilization. Theory based on studies made by deGlee concerning ground water movement caused by removing water from wells. Calcns. based upon observations rather than assumptions. Special studies pertaining to influence of tide in ocean and rivers on ground water level; effect of effective pptn., e.g., fraction of rain water added to ground water, studied with large lysimeters each 25 × 25 × 2.5 m. filled with dune sand. One lysimeter kept clean of growth, another covered with normal dune plants, third and surrounding area covered with different kinds of deciduous trees and fourth with pine trees. Treatment of ground water generally limited to iron and manganese removal, corrosion prevention and softening. More surface water will be needed; Rhine water has turbidity varying from 30 to 200 ppm. or higher, and highly pold.; lakes and ponds may contain color; special studies made to treat their surface waters by coagulation and settling. Of interest is work by Folpmers, who adds iron for coagulation by electrolytic method.

Water passes between 2 iron plates (1½ cu.m. apart) with low current supplied. Dosages can be accurately regulated and aided by super-chlorination of raw water. Studies on max. purif. of surface waters in smallest possible reservoirs based upon mass of short-circuiting data, which can be expressed in one formula showing frequency and age of effluent, e.g., time of detention of water. Slow sand filters still considered dependable for pold. surface water. Expts. have shown that reduction of area feasible and filtering veloc. of 300–400 mm./hr. permissible. Growth of one-celled and thread-forming algae formerly considered necessary. Studies have shown that disadvantages caused by growth may overbalance advantages. Exclusion of light is answer. Purif. by chlorination alone not considered important method in Holland; only as last barrier where biol. filtration may fail. Consumers object to chlorine taste, and physiological effect of continuously absorbing small quants. of chlorine must be considered. Many other studies under way, including bact. aftergrowth, effect of absence of oxygen in distr. systems on taste, org. base-exchange materials and fluorine.—*W. Rudolfs.*

A Trans-Jordan Desert Water Supply. The Relation Between Quantity and Salinity in Two Wells at Ma'an as Shown by Pumping Records. S. H. Shaw. Wtr. & Wtr. Eng. (Br.) **50**:333 (July '47). Wells supply Frontier Force Camp. First well, sunk in '28, 21.75 m. deep with static water level 18.05 m. from surface. Second well, sunk in '40, 18.7 m. deep with static level 15 m. from surface. Yield of older well is of order of 640 gph. (Imp.). New well did not yield more than 200 gph. Anals. in March '47 show:

	New well *ppm.*	Old well *ppm.*
Chlorine	200	192
Total hardness (soap)	380	440
Permanent hardness	200	230
pH	7.5	7.3

There is fundamental difference between Ma'an wells and some of those described in series of articles, "Water Supply in Middle East Campaigns." Former are distant from sea and considerable height above it, whereas some of latter confined to littoral area where direct influx of sea water may occur.—*H. E. Babbitt.*

The Water Supply of Bloemfontein [Un. S. Afr.]. Anon. Wtr. & Wtr. Eng. (Br.) **50**:301 (June '47). Source of munic. supply Modder R., 15 mi. from town. Two storage dams, one of 330 mil.gal. (Imp.) capac. and Mockes dam of 727 mil.gal. (Imp.) capac. near river. Spillways designed to pass 90,000 cfs. Raising of Mockes dam to increase storage capac. to 2000 mil.gal. (Imp.) has commenced.—*H. E. Babbitt.*

Water Works Showplace in South Africa. Eng. News-Rec. **139**:312 (Sept. 4, '47). Capetown's new Steenbras water works, built on mountainside 1000′ above sea, includes powerhouse, mixing and sedimentation basins, 20 rapid sand filters, chemical bldg. and clear well; provides 25 mgd. of water and 320 kw. of power.—*Ed.*

CHEMICAL FEEDING, CONDITIONING AND SEDIMENTATION

A New Concept of Coagulation. Harold R. Hay. Wtr. & Sew. Wks. **93**: 225 ('46). The currently accepted *agglomeration* theory recognizes formation of colloidal particles followed by agglomeration into floc which further increases in size from mech. collisions. Impurities removed by adsorption on colloidal particles and by entrapment in floc. Major emphasis on continuously growing floc. Discrepancies noted are: clarification occurs when particles highly dispersed, lack of explanation of decided "break," and clarity of water between floc particles. On basis of collision idea increase in coagulant concn. should increase time required for clarification, there would be no critical concn., and division of feed should not be disadvantageous, all of which contrary to observation. In proposed *protogel* theory is interposed a feeble gel structure formed after colloidal particles have developed sufficient size to interlock mechanically or bind through fields of force. This action enmeshes foreign matter. Shrinkage of protogel causes its disintegration and formation of small flocs, which grow in size by collision. Continued shrinkage increases their apparent density and tendency to settle. Whole mass of water, therefore, considered as held within protogel, and to pass through capillaries; this accounts for sparkling appearance between flocs. Flash mixing assures formation of all-inclusive protogel; high-

velocity conditioning breaks protogel and aids syneresis. In criticism, protogel of small enough pore size and sufficient strength to perform as ultrafilter hardly expected to form at such low concns. as common in water clarification. Exptl. evaluation of theory awaited.—*C. A.*

Electronic Coagulation. Fred E. Stuart Jr. Pub. Wks. **78**:27 (Apr. '47). In either pressure or gravity system water passed through series of aluminum sheets spaced at $\frac{1}{8}''$ intervals. Opposite elec. charges placed on alternate plates carry trivalent aluminum ions into water. Unit requires low-voltage, high-amperage direct current from rectifier or generator set. Current costs between 70¢ and $18.00 per mil.gal. Plate cost varies between 60¢ and $1.80 per mil.gal., using 4 to 12 lb. aluminum per mil.gal. Advantages claimed: faster floc formation, higher deg. of clarification, tougher floc and floc formation within wider pH range resulting in less careful control requirements.—*F. J. Maier.*

Possibilities of the Electronic Coagulator for Water Treatment. Charles F. Bonilla. Wtr. & Sew. (Can.) **85**:3:21 (Mar. '47). Electronic coagulator is cell contg. parallel Al sheets connected alternately to opposite poles of low-voltage d.c. Raw water is passed between plates, Al dissolves and $Al(OH)_3$ floc formed coagulates suspended matter as when alum added. Acid radical not simultaneously introduced as with alum and dosage more accurately controllable than by mech. chem. feed equip. Probably not all Al introduced available for flocculation but electrolytically formed floc may be more efficient than that formed from alum. Expts. made on Potomac R. water using small coagulator contg. 8 Al plates 0.064" thick spaced 0.125" apart, visual inspection indicating desirable amt. of floc, Al dissolved being theoretically equiv. to 86.6 ppm. alum. Probably half or less of this (about 43.3 ppm.) appeared as floc, rest forming insol. Al_2O_3. Data presented indicate that voltage required for given amperage decreased as test proceeded. With flow 4 l. per min., current consumption 5 amp. at 13.6 v., equiv. to 1080 kwhr. per mil.gal. Calcd., on basis of larger (1 cu.ft.) cell with 128 times above Al surface, that cost per mil.gal., exclusive of small overhead charges, $18–30, $14.05 of which for Al, compared with $12, exclusive of considerable overhead, power and handling, for equiv. treatment (43.3 ppm.) with alum and soda ash (if added to neutralize), following unit prices being used: alum $23, soda ash $21, sheet Al $480 per ton, and elec. energy delivered to cell 1.5¢ kwhr. Probably most economical cell size of order 1 cu.ft. for each 3–5 gpm. Energy cost would then be $2 mil.gal., and plates $\frac{1}{16}''$ thick on Potomac R. water would have to be renewed every 4–5 mo. Addnl. power economy attainable by closer spacing of plates and by using a.c., if practicable. Cell design could be improved to facilitate renewal of Al sheets. Performance data which should be detd. outlined. Concluded that, under suitable conditions, electronic coagulator may compete favorably with alum coagulation, especially in small installations and where pH of water should not be decreased.—*R. E. Thompson.*

Removing Suspended Matter From Water With Cold-Water Paste. Dutch 51,552 (Dec. 15, '41). Muddy water mixed with 20 mg. cold-water paste (prepd. with addn. of alkali) and 50 mg. $FeSO_4$ per l. Cold-water paste prepd. by mixing potato starch with equal quant. of water and 1% of its wt. of soda, then leading over heated rolls and drying paste. Suspended substances settle quickly.—*C.A.*

A Departure in Sedimentation Tank Design. Anon. Surveyor (Br.) **105**:506 (June 28, '46). Abstract of paper by K. Patterson, published in J. Inst. Civ. Engrs. (Br.) (Feb. '46). Paper on design, constr. and operation of water treatment plant at Mufulira Mine, N. Rhodesia, one of mines in Copper Belt. In '39 township consisted of 1700 Europeans and 17,000 natives, former being supplied with 700 gpd. (Imp.) per head, and natives with 30. No charge for water. Treatment necessary in '39. Hardness of 190 ppm. led to scale troubles. Author recommended 2 mgd. (Imp.) plant for aeration, sedimentation, filtration, and sterilization with chlorine. Principle (of new sedimentation basin design) was to admit water after dosing with floc-forming reagents through vertical slot in long, unbaffled rectangular tank from which water dischgd. over weir. Aim to obtain steady, streamlined flow. Design also promoted "leisurely" advance of water to outlet (of circular tank). This took form of drowned weir extending over more than quadrant of tank periphery and so located with respect to outlet that water would tend to pass completely around tank before passing over weir.

Expts. conducted in tank 22′ in diam. Tank finally constructed 78′ 6″ in diam., 12′ in max. depth, capacity of 357,000 gal. (Imp.) with retention period of 4¾ hr. Decanting weir and decanting channel for drowning occupy 100° of periphery. Before flowing into tank, water passes over aeration cascade and through mechanically agitated conditioning tank. Required high outputs maintd., and tank highly efficient.—*H. E. Babbitt.*

Triple Sedimentation Employed to Condition Culm-Laden Water. S. I. ZACK. Eng. News-Rec. **139**:115 (July 24, '47). Additional clarifier fitted with effluent channels offset from wall to double length of overflow weirs and rotary collector for continuous removal of sludge permits water with turbidity as high as 25,000 ppm. to be handled by water company at Norristown, Pa.—*Ed.*

Vaal River Water. Sedimentation and Chemical Treatment. J. P. LESLIE. Civ. Eng. (Br.) **41**:436 (Nov. '46). Vaal Dam, when full, impounds 234,471 mil.gal. (Imp.), and has max. depth above tailwater of 100 ft. Flow of Vaal R. at Vereeniging has fallen as low as 3 and as high as 166,000 cfs. It is not uncommon for river in flood season to carry 2000 ppm. suspended solids; on one occasion 7500 ppm. was recorded. Raw river water is abstracted at two intake stations about 3 mi. apart below Vereeniging and is pumped to purif. works, usual treatment being: (a) addn. of about 85.6 ppm. of hydrated lime containing 65% CaO, (b) intimate mixing for about 25 min., (c) primary sedimentation in hopper-bottom tanks, removing 90% suspended matter, (d) decantation and collection of settled water, then treatment with 3.6 ppm. alum, (e) secondary mixing, flocculation and at same time bubbling of carbon dioxide through water, reducing pH to about 8.2, (f) secondary sedimentation in hopper-bottom tanks removing additional 5% suspended matter. Water then passes through 72 rapid sand filters with total area of 43,350 sq.ft., normal rate being 63 gal. (Imp.) per sq.ft. per hr. Filtration removes about 4% suspended matter. Ammonium sulfate is added to filtered water at 0.4 ppm., and then chlorine at 0.4 ppm. After chloramination water is exposed to atmosphere before reaching consumers. Coliform organisms only occasionally found in 0.1 ml. of river water. Chloraminated water sent into supply contains on avg. 5 hot-growing organisms per ml. Chemicals added to water have little effect on analytical values of filtered water. Catchment area above barrage embraces area of 18,000 sq.mi. Two tributaries have marked seasonal effect on quality of raw water. Water as dischgd. from dam has normal hardness of 60–70 ppm.—*H. E. Babbitt.*

Turbidity and Suspended Solids in the Marseilles Canal. C. GOMELLA. L'Eau (Fr.) **34**:66 (June '47). Total quantities and relationship between turbidity and suspended solids of 608 samples of water collected between March 11, '44 and Nov. 30, '45, detd. by settling and filtration. Experimentation in a basin to det. amts. of material settled showed that from 77 to 87% suspended material removed, whereas the calcd. values were 77 and 90% respectively. On basis of Forel's theory that occulation of suspended material is due to an interposition of the particles between the eye and the bottom of the column of water, and assuming that the particles move incessantly at an even rate from the surface to the bottom, and considering unity of surface:

$$1 = nh\pi a^2$$

and: $$Ph = mnh \cdot 4/3\pi a^3;$$

or: $$Ph = 4/3ma$$

in which a = diam. of particle, n = no. of particles per unit volume, m = sp. wt. of particles, h = ht. of vision to the bottom, P = lb. of material in suspension per unit volume. In a mixt. of various sizes of particles, particles of the same dimension have generally the same sp. wt. The relations are:

$$1 = \pi h\Sigma n_1a_1^2$$

and: $$Ph = 3/4\pi h\Sigma n_1m_1a_1^3$$

or: $$Ph = \frac{4/3\Sigma n_1m_1a_1^3}{\Sigma n_1a_1^2}.$$

The product Ph is therefore 4 × the weight of the particles in suspension of the total surface. The error in h is in effect:

$$Ph = C^2$$

$$dP = \frac{dhC^2}{h^2}.$$

Since the dh residue is fixed, the error of the determination of P, apart from h, will be greater; and h is very small. The quant. of coagulant reqd. to obtain clarification is directly proportional to the lb. of material in suspension; hence clarification is a function of the product Ph, the nature of the coagulant, the physical-chemical character of the

water and the characteristics of the treatment basin. Studies of the Marseille Canal water show that the rate of coagulation corresponds to the turbidity of the water. *Example:* Temp. 20°C., alky. 57 ppm. CaO, pH 7.8, turbidity 50 cm., the rate of treatment with alum 10 g./cu.m., *P* corresponds to 28. The specific rate is therefore: 10/28 = 0.36 g./cu.m. A turbidity of 50 to 85 cm. corresponds to an equal rate of treatment for the specific rate multiplied by the lb. of material in suspension. The treatment required is therefore:

h	*P*	Rate *g./cu.m.*
50–55	28	28 × 0.36 = 10
60–75	24	24 × 0.36 = 8.5
80–85	17	17 × 0.36 = 6

Temp. has an effect on the rapidity of settling and will have some effect on the specific rates during different parts of the year.—*W. Rudolfs.*

CHEMICAL ANALYSIS

Combination Absorption and Titration Tube for Volumetric Determination of Carbon Dioxide. Earl J. Roberts. Anal. Chem. **19:**616 (Aug. '47). Carbon dioxide, evolved elsewhere during anal., bubbled in at least 50% excess of std. sodium hydroxide soln. contained in 2-arm absorption tube provided with cross tube and stirrer to circulate absorbent. After absorption completed, and excess of satd. barium chloride added, stirrer again started and excess alkali titrated with std. hydrochloric acid using phenolphthalein. Table of results shows highly efficient absorption.—*A. A. Hirsch.*

Colorimetric Determination of Free Chlorine With Methyl Orange. Michael Taras. Anal. Chem. **19:**342 (May '47). Definite reaction of 2 molecules of chlorine per molecule of methyl orange permits colorimetric detn. of free chlorine. A 100-ml. water sample is acidified with 1 ml. of 5*N* hydrochloric acid in order to adjust pH at or below 3.0 so that color variation of indicator elimd. Add 3 ml. of 0.005% methyl orange soln., invert tube twice, and compare with color stds. immediately. Stds., up to 0.65 ppm. Cl, also prepd. from methyl orange, stable for at least a month; fading insignificant for 3 mo. Upper limit of stds. extensible by adding 3 ml. of methyl orange. Temp. does not affect detns. Manganic ion exceeding 0.05 ppm. interferes. Nitrites incompatible with free Cl, and ferric ion interference by orange coloration requires several minutes standing. Chloramines cause slight color if reaction time prolonged.—*A. A. Hirsch.*

Tetraethylenepentamine as a Colorimetric Reagent for Copper. Thomas B. Crumpler. Anal. Chem. **19:**325 (May '47). Of several amines investigated, tetraethylenepentamine showed greatest sensitivity (extinction per cm. per ppm. of cupric ion). Blue color independent of excess reagent, stable, follows Beer-Lambert Law, and approx. 3.5 times as sensitive as ammonia. To 100 ml. portion of test soln., contg. 0–200 ppm. of copper, adjusted to pH 3.5 to 4.0, 10 ml. of 2% amine soln. added. This test subject to same interferences as with ammonia.—*A. A. Hirsch.*

Detection and Estimation of Microquantities of Cyanide. A. O. Gettler & L. Goldbaum. Anal. Chem. **19:**270 (Apr. '47). Prussian blue test enhanced by aerating acidulated soln. contg. hydrogen cyanide, derived from nitrogenous or cyanide-contg. substance, and passing gas through test paper impregnated with ferrous sulfate and caustic soda and retained between ground glass flanges. Limiting sensitivity 0.1 μg. of cyanide; test specific, without interferences.—*A. A. Hirsch.*

Estimation of Microquantities of Cyanide. Joseph Epstein. Anal. Chem. **19:**272 (Apr. '47). Cyanide or thiocyanate ion detd. colorimetrically by reacting with chloramine T and pyridine-pyrazalone reagent. In microgram quants. recovery ranges between 98 to 100%.—*A. A. Hirsch.*

Improved Dithizone Method for Determination of Lead. L. J. Snyder. Anal. Chem. **19:**684 (Sept. '47). Mixed-color micromethod at high pH described. To aq. lead soln. contg. potassium cyanide and ammonium citrate, ammonium hydroxide added until soln. reaches pH 9.5 to 10.0; lead, up to 450 micrograms, extracted with dithizone soln., and again separated with dil. nitric acid. After adjusting to pH 11.5 with ammoniacal cyanide soln., aq. soln. again extracted with dithizone and measured spectrophotometrically.—*A. A. Hirsch.*

2,2'-Bipyridine Ferrous Complex Ion as Indicator in the Determination of Iron. F. William Cagle Jr. & G. Frederick Smith. Anal. Chem. **19**:384 (June '47). Following reduction of iron in sulfuric acid soln. by passing through a Jones reductor, ferrous ion titrated by sulfato-cerate soln., using as indicator satd. aq. soln. of low-sol. ferrous perchlorate complex bipyridine ferroin. Color changes reversibly from orange to colorless at equivalence point.—*A. A. Hirsch.*

Polarographic Determination of Sodium or Potassium in Various Materials. J. H. Weaver & Louis Lykken. Anal. Chem. **19**:372 (June '47). With exception of spectrographic or flame-photometer methods, polography probably fastest of common methods for detg. these elements, especially in small concns. Procedures described for detg. sodium or potassium when variety of other materials present. Sample freed from reducible ions, and current-potential curve (polarogram) detd. for aq. soln. of alkali ion dild. in tetraethylammonium hydroxide, using dropping mercury electrode. Na or K concn. proportional to height of Na wave. Calibration first detd. on known soln.—*A. A. Hirsch.*

How to Test Water for Sulfates. C. A. Noll. Power. **90**:556 ('46). In method for detg. sulfate in water, sample of water made neutral to phenolphthalein by addn. of hydrochloric acid or sodium hydroxide, and then titrated in presence of isopropyl or ethyl alc., with soln. of barium chloride using tetrahydroxyquinone as indicator. When excess barium chloride present color of indicator changes from yellow to red. If phosphate present bromocresol green should be used instead of phenolphthalein in neutralization procedure. Method not suitable for detg. concns. of sulfate below 10 ppm. Chlorides, silica, sulfites, tannins and sol. salts of magnesium, calcium, and iron, do not interfere.—*W.P.R.*

Sulfite Waste Liquor Analysis. Determination of Sulfate by a Conductometric Titration Method. Quintin P. Peniston, Vincent F. Felicetta & Joseph L. McCarthy. Anal. Chem. **19**:332 (May '47). Cation exchange, through small glass tube filled with Amberlite IR-100, to replace Ca or Mg with Na in order to minimize errors due to adsorption on barium sulfate ppt., followed by mixing with equal vol. of isopropyl alc. to hasten stability of resistance readings. Formaldehyde elimd. interferences by sulfites. Standard barium chloride titrated into conductivity cell contg. mixt., continuing for several addns. beyond end point which is indicated by faster drop in resistance. From intersection on graph of conductivity against ml. of reagent, end point obtained with probable error of 1%. Time required 20 min.—*A. A. Hirsch.*

Apparatus for Rapid Conductometric Titrations. Lloyd J. Anderson & Roger R. Revelle. Anal. Chem. **19**:264 (Apr. '47). Electronic device, consisting of oscillator, power pack, bridge and voltmeter described for macro and micro detns. of sulfate. Use of seed crystals of barium sulfate for nuclei minimized effects of adsorption of other ions, produced more uniform ppts. and accelerated rate of pptn. Typical plot of data consists of 2 straight lines intersecting at end point. Usually suffices to plot only about 5 points before end point and equal number after. When controlled by seeding, 1 mg. of SO_4 may be detd. by titration with barium nitrate soln. within 1% error in presence of 50 times as much chloride. By seeding, titration time shortened from 30 to 5 min. Interference by calcium elimd. by use of oxalate.—*A. A. Hirsch.*

Water Analyses by Selective Specific Conductance. J. W. Polsky. Anal. Chem. **19**:657 (Sept. '47). Various ions detd. in water sample by measuring its specific conductance before and after addn. of definite const. quant. of precipitant. Adjustment of pH may be made at first if necessary. As excess of reagent required to assure removal of ion being detd., specific conductance of sample increased inversely as amt. of ion pptd. If reagent added to non-pptg. solns. of equal specific conductance, increase will be practically const., irrespective of particular salts present; but when added to solns. of different initial specific conductance, increase caused by given amt. of reagent will diminish with concn. of these ions, since ionic mobilities decrease with concn. Therefore correction must be applied to observed difference in specific conductivity, dependent on initial conductivity. Same cell must be used for detns. as for standardization. Prelim. curve of conductivity difference, in micromhos, first constructed, as for chloride, by measuring specific conductivity of 100-ml. samples of various concns. of sodium chloride (up to

100 ppm. as Cl) before and after adding 10 ml. of std. silver nitrate soln. (1 ml. = 1 mg. Cl). Indifferent electrolyte, sodium sulfate, prepd. to yield solns. of initial conductivity overlapping those for sodium chloride, and their conductivities likewise measured before and after addn. of 10 ml. of silver nitrate. These differences vary according to concn. of sodium sulfate. From max. difference, corresponding to initial conductivity of zero, are subtracted differences noted at various other initial conductivity values, to obtain corresponding correction for conductivity due to extraneous ions in chloride detn. This correction added to prelim. curve to establish final curve. Corrections checked numerically by other salts, such as sodium bicarbonate, magnesium sulfate and calcium nitrate. Similar procedures presented for sulfate and calcium, using barium chloride and sodium oxalate, resp., as pptg. solns. Results accurate to about 1–2% obtained on pure solns. and satisfactory agreements with *Standard Methods* generally shown for 4 different water samples. Surface-active phosphates, which retard pptn., interfere with sulfate and calcium tests, but leave chloride detns. unaffected.—*A. A. Hirsch.*

Color Filters in Filter Photometry. Stancil S. Cooper. Anal. Chem. **19**:254 (Apr. '47). Method developed for selecting proper light filter—for use with given colored soln., specified light source, and light-sensitive element—from data giving characteristics of light source and photosensitive cell, and from transmittancy factors of filter and soln. as function of wave length.—*A. A. Hirsch.*

Erratum

In the paper "Operating Characteristics of Synthetic Siliceous Zeolite" by L. Streicher, H. E. Pearson and A. E. Bowers (Vol. 39, p. 1142, November 1947 Journal), an editorial error altered the authors' intended meaning. In the second column beginning on the fourteenth line from the bottom of the page the statement which now reads:

> Silica losses during operation with Colorado River water, with an influent level of 17.3 ppm. of SiO_2, pH of 7.5 and temperature of 74°F., have always increased as the softening run progressed, as shown in Fig. 10. This has been observed consistently with three different zeolites. The change may be due to swelling or hydration effects.

should have read:

> Silica losses during operation with Colorado River water have always increased as the softening run progressed. This has been observed consistently with three different zeolites. The change may be due to swelling or hydration effects. The curves in Fig. 10 were derived from a run with Colorado River water with an influent level of 17.3 ppm. SiO_2, pH of 7.5 and temperature of 74°F.